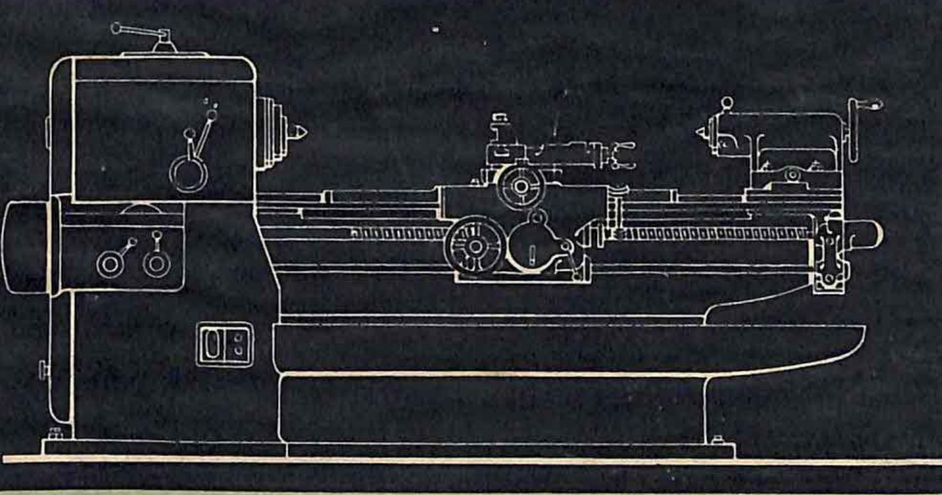
An Introduction to
WORKSHOP PRACTICE



A practical book for the apprentice
or junior engineering student

P. E. ELLIS

THIRD EDITION

DEPARTMENT
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COLLEGE

An Introduction to

WORKSHOP PRACTICE

is an elementary book for those who are starting their engineering training. It covers a wide range and gives a balanced description of all the main operations of the engineering workshop.

While this edition has been thoroughly revised to incorporate the main advances which have taken place in engineering practice, care has been taken to retain the simplicity of approach that was characteristic of the earlier editions.

A chapter has been added on Casting, Forging and Welding.

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AN INTRODUCTION TO

WORKSHOP PRACTICE

By

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AUTHOR'S NOTE

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In this book I have attempted to give an outline of the knowledge that is required in the workshop or classroom by the apprentice or junior engineering student. My aim has been to produce a book which will be found useful by the beginner.

Space has not permitted me to deal with each subject at length, but the sequence I have adopted is based on long experience of industrial conditions and of teaching. I wish, however, to warn young students against the danger of thinking of the various processes of engineering as isolated subjects with no inter-connections. On the contrary, if efficient production is to result, these processes must be visualized as parts of a coherent whole.

I wish to thank James Neill & Co., Ltd., Sheffield, for permission to use information about their non-electric magnetic chuck; also Mr. Gordon Rose, for revising the manuscript.

In this *third* edition a chapter has been added on Casting, Forging and Welding. This has been written from the point of view of the machine shop or drawing office apprentice rather than that of the foundryman.

P. E. ELLIS.

NOTE.—In accordance with a regulation of the London County Council, it must be mentioned that the Council accepts no responsibility for the opinions and conclusions of its teachers.

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CHAPTER I

Industrial Metals: Their Properties and Uses

In discussing the properties of metals, the following technical terms will be used from time to time. They require some explanation, especially as in many cases alternative words exist which have the same meaning.

Tensile Strength

The strength of a metal when broken in a tensile testing machine. It is stated numerically as the greatest load divided by the cross-sectional area of the test piece (tons per sq. in.). Also called Ultimate Tensile Stress (U.T.S.), or Tenacity.

Ductility

The capacity of a metal to stretch without breaking. It is usually measured by the percentage stretch when a standard test piece is broken in a tensile testing machine. Copper is a highly ductile metal. *Malleability* means " Capacity to be formed by hammering ". This is almost the same thing as ductility, and the two words are often used interchangeably.

Toughness

A combination of Tensile Strength and Ductility. A tough metal has a high resistance to shock. *Brittleness* is the tendency of a metal to fracture on receiving a blow—the opposite of Toughness.

Hardness

The ability to resist surface indentation and wear. Often associated with brittleness.

Fusibility

All metals are fusible, i.e. they can be melted. Those that melt at a low temperature are referred to as "easily fusible"; those that melt at a high temperature as " refractory ".

Elasticity

Elasticity means the tendency of a metal to spring back to its original form after being forced out of it. Lead, for example, has a low degree of elasticity.

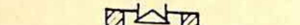


Fig. 1.—Blast Furnace

Industrial Metals

Cast Iron

Pig iron is obtained by charging a blast furnace (fig. 1) with iron-ore, coke and limestone. As the charge gradually sinks down to the bottom of the furnace, the limestone and the impurities from the ore form a fusible slag, which floats on top of the molten metal and is blown off at intervals. The furnace is then tapped and the iron is run off into " pigs ", i.e. oblong moulds.

There are two types of pig iron: grey iron and white iron. Grey iron has a crystalline or granular structure, is very fluid when melted, and is used for ordinary castings. White iron has a white, close-grained appearance, is dead hard, and is chiefly used for the manufacture of wrought iron and steel.

Pig iron contains about 4 per cent of carbon.

When pig iron is re-melted and run into moulds cast iron is formed. Cast iron is strong in compression (45 tons per sq. in.), but brittle, and weak in tension (9 tons per sq. in.).

High Duty Cast Irons

These irons are made by alloying ordinary cast iron, and modifying the casting technique. They have properties between cast iron and mild steel, and are used for important and intricate castings. Such castings are almost as strong as mild steel and much cheaper.

Wrought Iron

Wrought iron is a fairly pure form of iron. It is malleable and ductile, and its fibrous structure, produced by its elongation during forging, makes it a most useful material for parts which are required to withstand intermittent shocks, such as links, chains, railway wagon couplings, and hooks. Wrought iron is manufactured by the puddling process in a reverberatory furnace (fig. 2). Pig iron is placed in the furnace and heated. At first the iron melts. Small quantities of ore are then fed in and the oxygen contained combines with the carbon in the iron to form a gas (carbon monoxide). The escape of this gas in the form

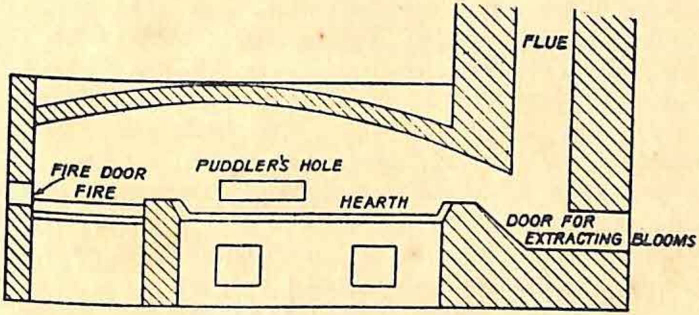


Fig. 2.—Reverberatory Furnace

of bubbles gives the appearance of boiling while the carbon is being removed. During this stage the slag is worked into the molten metal, to facilitate oxidation. When the carbon has been almost completely removed, the metal stiffens, as it now has a higher fusing point. The metal. now in a pasty condition, is hammered into so-called " blooms ", which are passed through rollers in order to squeeze out the slag. The processes of heating, hammering and rolling are then repeated; each time this is done the quality of the iron is improved. Finally the wrought iron is rolled when hot into bars of various sections. Wrought iron is never cast. Its tensile strength is 23·6 to 28 tons per sq. in.

Steel

Steel is manufactured by several different methods:

(1) In the Cementation process, bars of wrought iron are placed in large boxes and packed round with carbonaceous matter, and are then heated for several days. The carbon combines with the iron and forms so-called " blister steel "

On removal from the furnace the bars of blister steel are broken into pieces about 18 in. long, and are tied together in bundles by strong steel wire. After being raised to a white heat they are hammered and rolled into bars of "single shear" steel; if the heating, hammering, and rolling are repeated, "double shear" steel is produced.

Cast steel is formed when bars of blister steel are broken into pieces and melted in a crucible.

(2) In the Bessemer process, the steel is produced by the Bessemer converter. Molten cast iron is placed in the converter and a blast of hot air is blown through it, burning out all the carbon, and thus leaving pure iron. To this is added a compound of iron, carbon, and manganese. The amounts of these added determine the grade of steel produced.

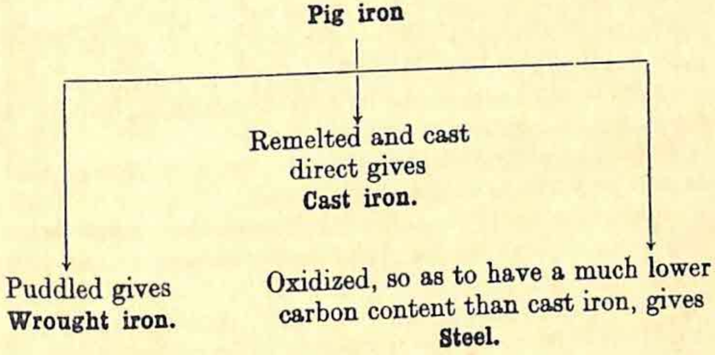
(3) The Open Hearth process, which is similar to the Puddling process. A larger and more efficient furnace is used which is hot enough to allow the steel to remain liquid even after the carbon has been removed. This process

is rather more expensive than the Bessemer but is capable of better control.

The Open Hearth and Bessemer processes account for most of the steel that is produced.

When the amount of carbon present in the steel is less than ·25 per cent, the latter is termed " mild steel ". This does not harden when heated and plunged into water. If the amount of carbon is increased, the steel acquires the property of hardening when it is heated and then suddenly cooled in water.

The following table briefly illustrates the process by which the pig iron originally produced from the ore gives rise to each of the three commercial products just described.


Pig iron
Remelted and cast direct gives **Cast iron.**
Puddled gives **Wrought iron.**
Oxidized, so as to have a much lower carbon content than cast iron, gives **Steel.**

Classification of Steel

Carbon is the most important alloying element in steel and largely determines its properties. The following table gives the main grades of steel and their uses.

In this table the word " alloyed " means that one or more relatively expensive metals have been deliberately added to improve the steel. All steel contains certain impurities, some of which are beneficial. These are not classed as alloying elements unless they are present in very unusual proportions.

GRADES OF STEEL

Description	Carbon Content	Use	Remarks
Mild steel.	·1–·25%	Structural and general engineering steels.	
Medium Carbon.	·25–·5%	High-duty machine steels.	Frequently alloyed.
Tool steels.	·5–1·25%	Tools and other machine parts which require hardening.	Frequently alloyed.

Copper and its Alloys

Copper is the best electrical conductor of all the common metals. It is therefore widely used in the electrical trades for making wire and other conducting parts of electrical machinery. It is a highly ductile and tenacious metal and is easily worked either hot or cold, although in drilling or tapping its toughness is very noticeable.

Brass is an alloy of copper and zinc. Its properties depend on the proportions of these two metals.

70/30 brass (i.e. 70% copper, 30% zinc) is a yellow brass which is soft and ductile. This makes it very suitable for press work.

60/40 brass. This is used mainly for castings of valves, etc. It is harder and less ductile, but can be forged hot.

All brasses have good corrosion resistance, are good electrical conductors and can be easily soldered.

Bronze is an alloy of copper and tin. It has superior properties to brass but is more expensive because of the high price of tin. There are also alloys containing both zinc and tin, which have properties intermediate between bronze and brass.

Aluminium and its Alloys

This metal is about half the weight of steel. In its pure form it is naturally soft and very ductile. It is a very good conductor of electricity and heat, and has fair resistance to ordinary corrosion. Its tensile strength and hardness can be greatly increased by cold working.

Aluminium Alloys have strengths comparable with mild steel. Copper is the chief alloying element, but as several others are used there is a very large number of these alloys each having advantages for its special purpose.

Some alloys require heat treatment to bring out their best qualities, others do not.

As aluminium has a low melting point all these alloys lose their strength at quite a moderate temperature.

Anti-friction Metal

This is frequently called Babbitt's metal and is used very largely for bearings. The alloy is sometimes 80 per cent tin and 20 per cent antimony, but it often contains copper or lead and zinc. There are numerous mixtures for anti-friction metal; they are adapted to suit the speed and weight of the shafting to be supported.

Lead

Lead was one of the earliest metals to be used. When pure it is soft, ductile, malleable and almost non-elastic; it can even be cold-welded by pressure. Owing to its resistance to corrosion, lead is useful for roof coverings, pipes, gutters and all sanitary work; it is also used very largely in chemical works.

High-speed Steels

These steels are used for the cutting tools of lathes and other machine tools. They are high carbon steels with heavy additions of tungsten and other rare metals. The purpose of these additions is to prevent hardness from being " drawn " by the great heat which is developed during cutting.

Stellite and Tungsten Carbide

These materials will maintain their hardness even up to a dull red heat and so permit metal cutting at even faster speeds. They are not steels and cannot be softened by any heat treatment. This is a grave disadvantage for many purposes.

CHAPTER II

Hardening, Tempering and Case-hardening

In the workshop a number of different grades of steel are used in the manufacture of various articles, and the grade is selected in each case for its strength and wear-resisting qualities. Steels may be divided into two classes: (1) Carbon steels; (2) Alloy or Special steels.

Carbon Steels

These are divided into four classes.

(1) Soft, low-carbon (or mild) steel, containing from ·05 to ·20 per cent of carbon. This steel cannot be hardened and tempered by the usual method of heating and quenching, but may be case- (or surface-) hardened.

(2) Medium carbon steel, containing from ·2 to ·4 per cent of carbon. This steel can only be slightly hardened.

(3) Hard carbon steel, containing from ·4 to ·7 per cent of carbon. This steel can be hardened and tempered.

(4) Hard carbon or cast steel, containing from ·7 to 1·5 per cent of carbon. This steel can be fully hardened.

It is clear, therefore, that one of two methods of treating steel must be adopted: (*a*) case-hardening or (*b*) hardening and tempering. We shall meanwhile confine ourselves to the latter, leaving the subject of case-hardening until later (see p. 12).

Hardening

The term *hardening* refers to the property which a high-carbon steel possesses of becoming "dead hard" or "glass hard" when heated to a cherry-red and quenched in a liquid. This treatment leaves the steel in its hardest and strongest condition, but very brittle. In many cases, for instance, where the metal has to withstand shocks or blows, the steel so treated would be too brittle. For tools such as lathe tools and chisels, the brittleness would cause the cutting edges to break. It is therefore necessary to reduce the brittleness without sacrificing too much of the hardness and strength. The process known as "tempering" has this result.

Tempering

Tempering consists in heating the steel, after hardening, to certain temperatures and then quenching again. The beginner may practise this with a cold chisel. The cutting end must first be heated (to about an inch from the edge) and then quenched in water or oil. After quenching, the heated end will be dead-hard or brittle. It is now cleaned or polished with emery cloth, then heated just above the hard section as shown in fig. 3.

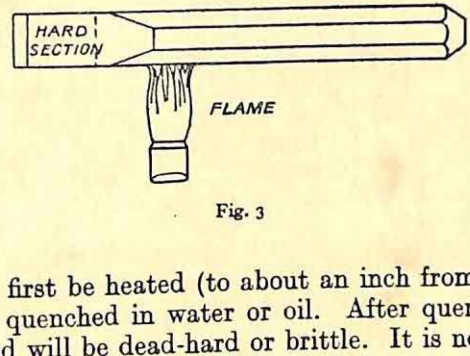


Fig. 3

As the heat is applied, a series of colours ranging from very light straw (450° F.) to dark blue (570° F.) will be seen to travel towards the cutting edge. When the required colour, in this case a dark purple, reaches the cutting edge, the chisel must be quickly plunged into water. It will then be tempered. Ice-cold water must not be used for quenching, as this would cause cracks to appear in the steel.

The various colours, which are due to a film of oxide on the cleaned surface, indicate the different temperatures reached and the corresponding degrees of hardness produced. The following table gives the colours, temperatures, and purposes for which the corresponding temper is suitable.

TEMPERING SCALE

Colour	Temp. F.	Use
Dark blue	570°	Springs, Screw-drivers, Cold chisels for wrought iron.
Dark purple	550°	Cold chisels for cast iron and steel.
Light purple	530°	Augers.
Yellow purple	520°	Flat drills for brass, Twist drills.
Brown yellow	500°	Reamers, Punches, Dies.
Very dark straw	490°	Chasers, Taps, Screw-cutting dies.
Medium straw	470°	Boring cutters.
Light straw	450°	Milling cutters, Planing tools (for iron).
Very pale straw	430°	Steel planing tools, Hammer faces, Light turning tools, Scrapers for brass.

Smaller steel tools cannot be tempered in this way. They are first raised to a red heat and quenched in an oil bath. Then they are tempered by reheating on a hot metal plate or in a hot sand bath until the correct colour appears, and quenching in water.

High-speed Steels

High-speed steels require a heat treatment which is similar to that for carbon steel. The main difference is that both the hardening temperature and the tempering temperature are raised. The hardening temperature (cherry red for carbon steel) becomes "white heat", and the tempering temperature becomes "dull red". These temperatures are critical and it is not satisfactory to work by eye.

Heat-treatment Equipment

The traditional method of heating tools for hardening was in a blacksmith's forge. As a substitute, a powerful gas blow-lamp can be used. These methods are effective but require considerable skill if consistent results are to be obtained, especially when working with high-speed steel. Much more reliable results can be obtained by using either a "muffle" furnace or a salt-bath furnace. The muffle furnace is an enclosed brick-lined chamber heated by gas or electricity to the required temperature. The atmosphere is usually controlled to be chemically "neutral" so that the steel is not oxidized. The temperature is registered by a pyrometer and is usually controlled by a thermostat of some kind. Such a furnace will heat the work much more evenly than is possible by cruder methods.

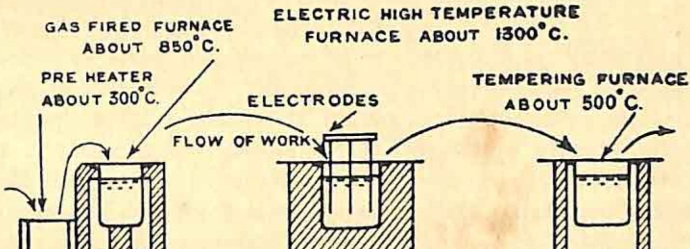


Fig. 4.—Layout of salt-bath furnaces for high-speed steel tools

An even more efficient method both for speed and accurate control is by the use of a salt-bath furnace. This consists of a pot containing a molten salt which is maintained at the working temperature. This type of furnace is capable of handling large quantities of work in very strict control. The plant, however, is costly and the time taken to heat up the furnace is considerable, so the method is suitable only where there is a large volume of work. In practice this usually means that salt-bath furnaces are used only where it is worth while to have a special heat-treatment shop.

Case-hardening

It is often necessary to produce a steel which will resist wear and at the same time not be brittle. This can be done by case-hardening, i.e. adding carbon to the outer surface of low carbon steel, as in fig. 5. As we have seen, mild steel or low carbon steel will not harden in the ordinary way, but by adding carbon to the outer surface, the surface is made hard, while the core or centre remains soft and fibrous. The depth to which the carbon penetrates, that is, the thickness of the hardness, depends on the length of time for which the steel is exposed to the carbonizing mixture.

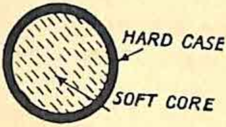


Fig. 5

Some good case-hardening materials are: wood charcoal, animal charcoal, bone charcoal, leather, lamp-black, and a mixture of ninety-five parts of wood charcoal and five parts of soda ash. Good results may also be obtained from certain chemicals, such as potassium cyanide, potassium ferrocyanide, and a mixture of potassium ferrocyanide and potassium bichromate. In addition, there are on the market many manufactured compounds which will be found much more convenient by those attempting case-hardening for the first time.

A simple workshop method of case-hardening for small parts, such as pins, collars, brushes, nuts and washers, consists in heating the parts to a cherry-red heat and dipping them into or sprinkling them with the compound used. This operation is repeated several times, care being taken that the parts which are to be case-hardened are covered with the compound. The depth of hardness depends on the number of times the process is repeated. Finally, the article is raised to a red heat and quenched in water.

The best commercial method of case-hardening is known as the liquid bath method. The heated steel is placed in a molten hardening liquid. Among the so-called hardening liquids are solutions of potassium cyanide and sodium cyanide. The length of time for which the steel is left in the bath depends on the temperature of the bath and the thickness of the hardness required, varying greatly with the type of article being hardened. When the carbonizing or case-hardening is completed, the articles are taken out and the cyanide is allowed to drip from them before they are quenched in water. This method gives a good uniform hardness and is very suitable for delicate tools, owing to the small amount of distortion of these tools during carbonizing. It is therefore very widely adopted at the present time. Sometimes only a portion of the steel has to be case-hardened. This can be done by plating with copper the portion which is to be left soft, as the carbon will not penetrate the copper.

Warning.—On account of the highly poisonous nature of the chemicals used in case-hardening, and the danger from their fumes, the greatest possible care must be taken in their use.

Annealing

Annealing is a process of heating and allowing the steel to cool very gradually; the more gradual the cooling, the softer the steel. After the forging, hammering or rolling of steel, the metal, not having a uniform hardness, is in an uneven state of stress, which impairs its strength. To remove this internal stress, the steel is annealed, i.e. heated to a uniform red heat and allowed to cool evenly and slowly. After it has been annealed, steel is in its softest and most ductile state.

The best workshop method of annealing is to heat the steel in a closed-in furnace for two to three hours; then the heat is shut off and the steel is allowed to cool with the furnace. If no furnace is available, small articles can be annealed by heating them to a red heat in a bed of red-hot coke, surrounding them completely with the red-hot coke, and allowing the whole to cool slowly. This method, although very successful with small articles, would not give satisfactory results with larger work.

The heat treatment of steel in modern workshop practice is very important, and it has only been possible to deal very briefly with the subject here. The cost of producing tools and gauges is so great that careful heat-treatment becomes essential. Since the hardening of these expensive tools demands careful attention, the work of the hardening shop is extremely important.

CHAPTER III

The Use of Hand Tools

Files

The file is the most important of an engineer's hand tools, and must be used skilfully if successful work is accomplished; indeed, very little work at the bench can be done without it. Hence it is very necessary that the characteristics and handling of the file should be fully understood and mastered; for it is only when any tool is thoroughly understood and mastered that the best results can be obtained from it.

The various types of files are distinguished by their length, cut, and shape or sectional form. According to the British Standard Specifications, there are twenty-four different shapes of files. We shall not deal with all of these types, but only with the most common and best known.

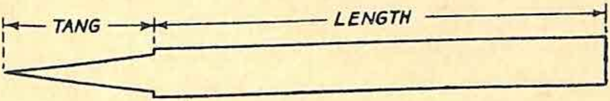


Fig. 6

Length

This is always measured along the edge, excluding the tang (fig. 6). Lengths vary from 3 to 12 in., and the required length depends entirely on the work in hand.

Cut

This term refers to the grade of fineness of the teeth, which are cut obliquely across the face and edge of the file. There are five grades: Rough, Bastard, Second Cut, Smooth and Dead Smooth.

The teeth are cut in the steel blank while it is still soft. At one time they were cut by hand but are now always machine cut. Files are then made dead hard, but the tangs are left soft.

Shapes

The commoner shapes are shown in fig. 7. Unless otherwise stated all files are made slightly tapered and convex down their length. This enables the file to get an adequate bearing pressure on a large flat surface.

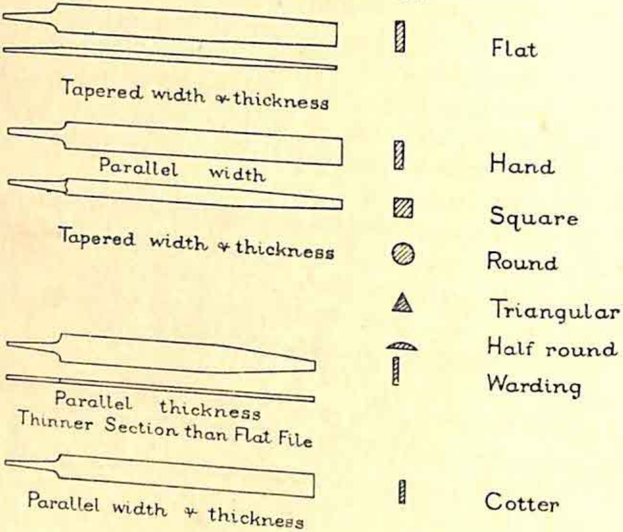

Flat
Tapered width & thickness
Parallel width
Hand
Square
Tapered width & thickness
Round
Triangular
Half round
Warding
Parallel thickness
Thinner Section than Flat File
Parallel width & thickness
Cotter

Fig. 7.—File shapes

Some flat files have a so-called safe edge. One edge has no teeth, and this enables the file to be used in a corner without filing more than one surface (fig. 8).

The Use of the File

It is not easy to explain in words how to use a file so as to make it move in a true plane. Anybody can push a file; anybody can remove metal, and possibly fit two pieces together, but this is not filing as understood by the skilled worker. A fine sense of touch and the ability to move a file in a true plane are not easily acquired.

The beginner is always faced with the difficulty of finding his work becoming convex (fig. 9). This is easily explained. Owing to the nature of its teeth, a file cuts on the forward stroke only. In order to file correctly it is necessary to hold the handle of the file with the right hand, the left hand being at the other end. Begin by moving the file forward, then backward, with pressure on the forward stroke only. It will be found that in attempting to push the file forward, in addition to applying pressure for cutting, the *right* hand tends to fall at the commencement of the stroke (fig. 10).

In continuing the movement forward, the tendency will be the same until near the end of the stroke; the *left* hand then falls, and so a convex surface is produced instead of the flat surface aimed at (fig. 11).

With patience and continued practice, it will gradually be found easier to counteract the tendency towards a rise and fall of the left hand, and the proper action will gradually be acquired. Some writers on this subject have stated that the position and swing of the body play a very important part in the use of the file. This is true; it must be pointed out, however, that the worker should first acquire a natural and unconscious habit of filing flatly; he will then have adopted the position which is best suited to himself. Positions of different workers are by no means the same, but may be equally effective. In the process of acquiring perfect action in the use of a file, each worker unconsciously makes the necessary adjustment in the position of the feet and body which is best suited to his height and physique. The average speed in filing is sixty strokes per minute.

For preference, new files should be used for soft metals, such as copper, brass, bronze and aluminium. A worn file will not act effectively on these soft metals, because the

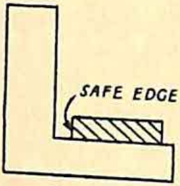


Fig. 8

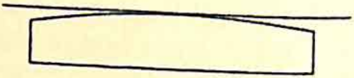


Fig. 9

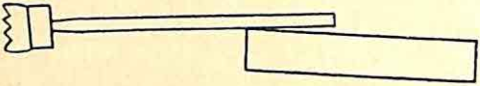


Fig. 10

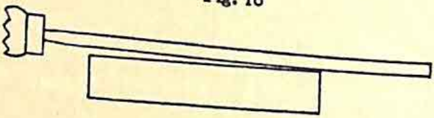


Fig. 11

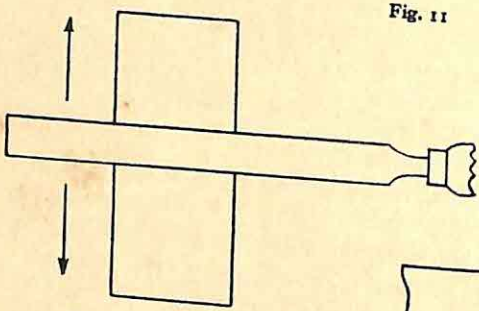


Fig. 12.—Draw-filing

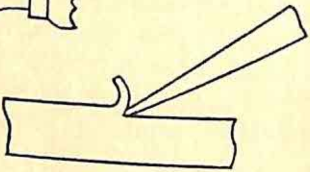


Fig. 13

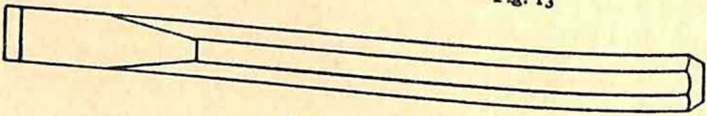
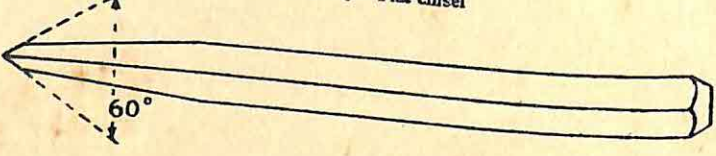


Fig. 14.—Flat chisel



teeth are not keen enough to penetrate when there is so little resistance.

Care should be taken not to allow the teeth of the file to touch the hardened jaws of the vice.

Draw-filing

Work that has been filed flat should be finished by draw-filing. For this operation, the file should be held by both hands, one at each end, and moved to and fro lightly over the work (fig. 12).

By this method, using a second cut file, the marks made by cross-filing may easily be removed.

Pinning

When a second cut or other fine file is used, the teeth sometimes become choked with pieces of metal, causing the file to scratch the work. These pieces of metal can be removed by a wire brush or file card. Chalk rubbed on the file before it is used will largely prevent this.

The following hints will be found useful:

Do not throw files down among other tools, as this may damage the teeth and even break small files.

Do not form the habit of using emery cloth when a file should be used.

Do not use a file without a handle, as this is dangerous.

With fine files, use the file card frequently.

Chisels

Of the other hand tools, perhaps the chisel is that most used. It is usually made of hexagonal cast steel, with the cutting edge tempered to dark purple.

Its uses are so varied that the results depend almost entirely on the skill of the worker. Fig. 13 shows a flat chisel in action, and the approximate angle at which it should be used.

It is not advisable to hold the chisel with a rigid grip, as this will quickly tire the hand. A light easy grip is sufficient, as this secures the complete control of movement necessary to follow up the cut. The mistake is often made of fixing the eye on the head of the chisel, thus losing sight of the cutting edge. Many learners are afraid of hitting their grasping hand with the hammer if they watch the cutting edge, but a little practice will soon give them the confidence necessary to enable them to use the chisel correctly.

The following are the most common shapes of chisels and their particular uses:

Flat chisel, used for ordinary surface cutting and made in various lengths and widths (fig. 14).

Cross-cut chisel, used for cutting keyways by hand, also for cutting grooves (figs. 15, 16).

Round-nose chisel, used for cutting concave flutings, such as oil grooves (fig. 17).

The Hacksaw

The hacksaw is used to saw through metal by hand. It has an iron frame, with a blade which is held by a pin at each end; the degree of tension on the blade, which is usually adjusted by use of a wing nut, is a matter of judgment, and depends to a certain extent upon the length of the blade (fig. 18).

A useful length of blade is 10 in., but a saw with an adjustable frame will take a blade of from 8 to 12 in.. The saw frame and saw should be manipulated in the same manner as a file. Additional care must be taken with a new blade, which is tempered very hard, as the teeth are very keen and very easily snap off. Hacksaw blades have from 14 to 32 teeth to the inch, a fine toothed blade being generally used for thin plate and tubes, and a coarse blade for thicker metal. A good average speed when using a hacksaw is sixty strokes per minute.

It is very difficult to saw *thin* plate, and a good plan is to place it between pieces of wood (fig. 19). This will prevent the teeth snapping.

The power hacksaw is a useful tool. The work is held in

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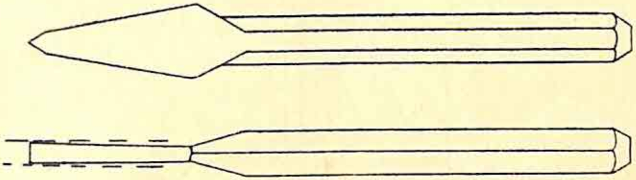

Fig. 15.—Cross-cut chisel

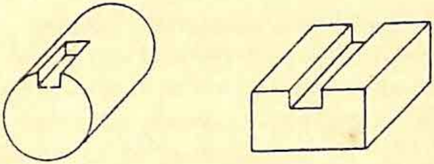

Fig. 16

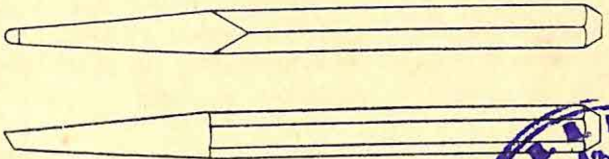

Fig. 17.—Round-nose chisel

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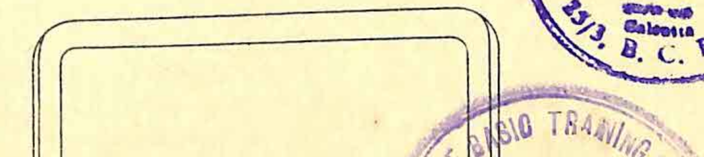

Fig. 18.—Hack saw

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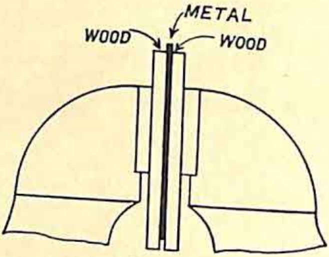


Fig. 19

a vice, and the saw works with a reciprocating motion very similar to a hand hacksaw. The rate of cutting is adjusted by shifting a movable weight on the frame of the machine. A mechanical arrangement is usually provided to raise the saw on the return stroke so as to avoid unnecessary wear of the blade.

CHAPTER IV

Measuring Tools

To produce accurate work it will be found necessary to have, and to be able to use, good measuring tools. We shall deal with these tools in the order in which the beginner should become acquainted with them.

Steel Rule

A good steel rule is always necessary, particularly for testing a flat surface, and measuring lengths, approximate diameters, or the depths of slots or holes. Steel rules may be obtained in lengths from 6 to 24 in. Good flexible steel rules for measuring curves can also now be obtained.

Try-square

The simple try-square (fig. 20) is one of the most useful measuring tools. Its utility depends largely upon the type of work in hand. It may become out of true after long use. A simple method of testing the truth of a square is shown in fig. 21:

First place the square against the edge of a perfectly flat surface, and with a very fine sharp point mark a line on the flat surface along the edge of the blade. Now reverse the square, and if the edge of the blade coincides with the line, the square is true. If the edge does not coincide the square is out of truth to the extent of half the angle which the reversed square makes with the original line.

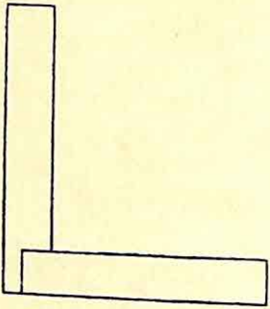


Fig. 20.—Try-square

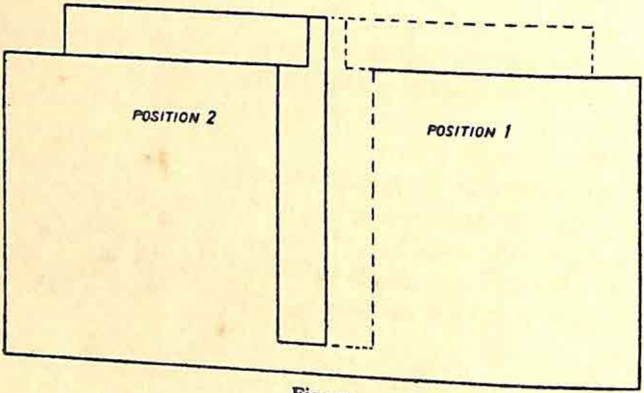


Fig. 21

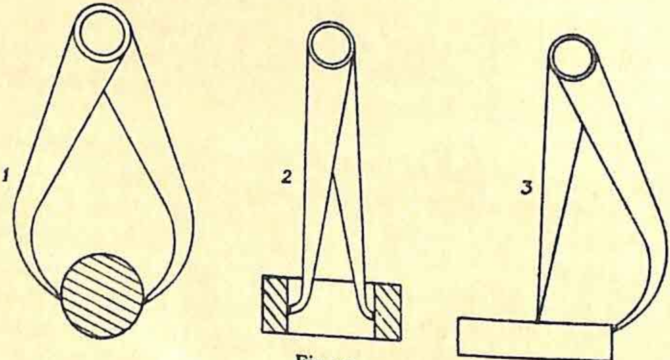


Fig. 22

Calipers

Calipers are used for measuring distances between or over surfaces, or for comparing sizes with a rule. This means that the calipers may be first used to test the work and then to check the measurement on a rule; or the work may be tested after the calipers have been set by the rule.

Fig. 22 shows: (1) outside calipers for testing external diameter or thickness; (2) inside calipers for measuring internal dimensions; (3) Jenny calipers used for marking lines at certain distances from an edge.

Errors often result from the incorrect use of calipers. Fig. 23 shows correct and incorrect methods of using them. It will be seen that the correct method secures for one leg of the calipers a positive position for testing or checking dimensions.

Micrometer

However carefully a rule may be used, the degree of accuracy obtained does not meet the requirements of precision work. By means of a micrometer one can measure to ·001 in. with fair ease and to ·0001 in. in very favourable conditions.

The work is placed between the rod R (fig. 24) and the anvil A, which is fixed to the frame F. The rod R is fixed to the thimble T, and is revolved by a screw with forty threads to the inch. One revolution of the thimble moves the rod $\frac{1}{40}$ of an inch. The thimble is divided into 25 equal parts (fig. 25); therefore one division on the thimble $= \frac{1}{25} \times \frac{1}{40}$ in. $= \frac{1}{1000}$ in. The sleeve S is divided into main divisions and sub-divisions (fig. 26). One revolution of the thimble, which is $\frac{25}{1000}$ in. (·025 in.) corresponds to one sub-division. Four revolutions of the thimble = 4 sub-divisions or 1 main division. Hence 1 main division = $\frac{100}{1000}$ in. (·1 in.). A very quick method of using a micrometer is to read (1) the number of main divisions, (2) the number of sub-divisions, and (3) the number of divisions on the thimble. Fig. 27 shows a micrometer set at ·685 in.:

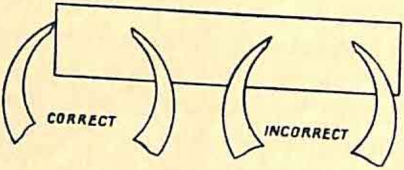


Fig. 23

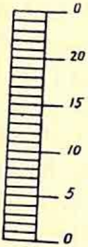


Fig. 25

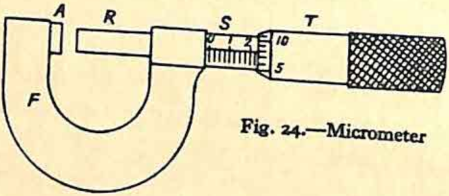


Fig. 24.—Micrometer

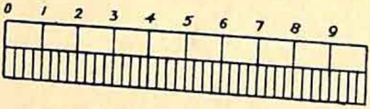


Fig. 26

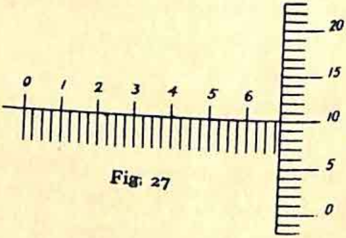


Fig. 27

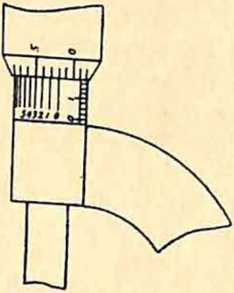


Fig. 28

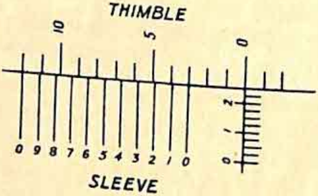


Fig. 29

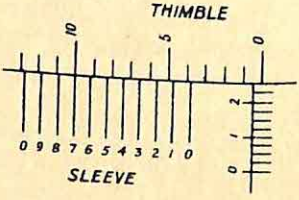


Fig. 30

6 main divisions = ·6 in.
3 sub-divisions = ·075 in.
10 divisions on thimble = ·010 in.
= ·685 in.

Some micrometers are fitted with vernier scales which read to ·0001 in. (figs. 28–29). These fine readings cannot be relied upon unless the greatest care is taken in "applying" the micrometer. The slightest variation in the force used in screwing up the micrometer will give errors greater than ·0001 in. The best method of taking a very fine measurement is to compare the diameter of the part being measured with that of a standard roller which is nearly the same size.

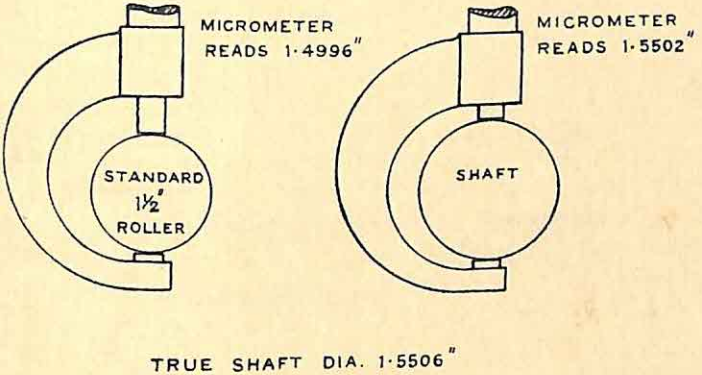


Fig. 30.—Taking a fine measurement

Inside Micrometer

The internal micrometer in fig. 31 (p. 28) differs from the ordinary micrometer in that the scale on the sleeve runs in the opposite direction. It is used for measuring internal dimensions.

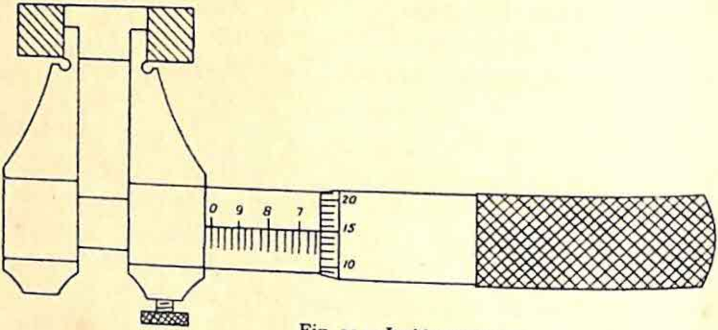


Fig. 31.—Inside micrometer

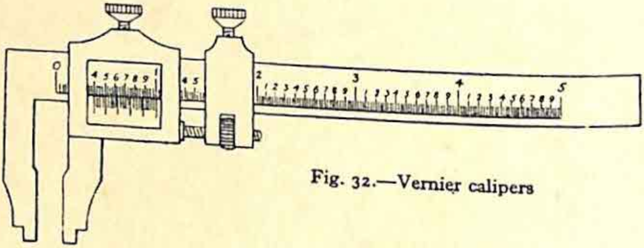


Fig. 32.—Vernier calipers

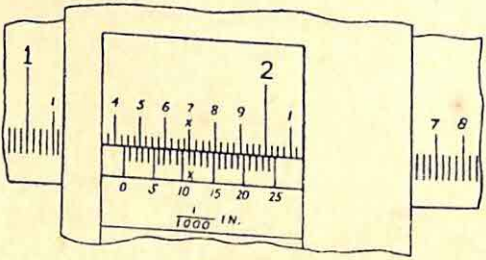


Fig. 33

Vernier Calipers

The vernier calipers (fig. 32) are useful inasmuch as they give a direct reading on the scale to $\frac{1}{1000}$ of an inch. The main scale is divided into inches, tenths and fortieths, and the 25 divisions on the vernier are equal to 24 divisions on the main scale. The difference between a division on the vernier and a division on the main scale is $\frac{1}{25} \times \frac{1}{40}$ in. $=$ $\frac{1}{1000}$ in. If the tool is set so that the 0 line on the vernier coincides with the 0 line on the bar, the first line to the right of the 0 line on the vernier will be distant $\frac{1}{1000}$ in. from the 0 line on the bar. The difference increases by $\frac{1}{1000}$ in. for each division until the 25 on the vernier coincides with the 24 on the bar. To read the tool, first note how many inches, tenths (·100), and fortieths (·025), the 0 mark on the vernier is from the 0 mark on the bar; then note the number of divisions on the vernier from the 0 line to the line which exactly coincides with a line on the bar. Fig. 33 shows the vernier moved to the right one, four-tenths and one-fortieth inches (1·425) on the bar, and the eleventh line on the vernier coinciding with a line (indicated by a cross) on the bar. Eleven-thousandths of an inch are therefore added to the reading on the bar, and the total reading is one, and four hundred and thirty-six thousandths of an inch (1·436).

Depth Gauges

These tools are used for measuring the depths of holes. Fig. 34 (p. 30) shows a simple type of depth gauge, and fig. 35 a micrometer depth gauge.

Protractor

The protractor is used in the measurement and setting out of angles. A simple type is shown in fig. 36, but there are many designs. The arm A is moved to the required angle and locked by the nut B.

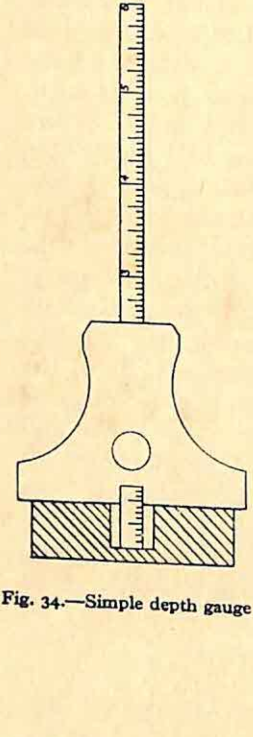


Fig. 34.—Simple depth gauge

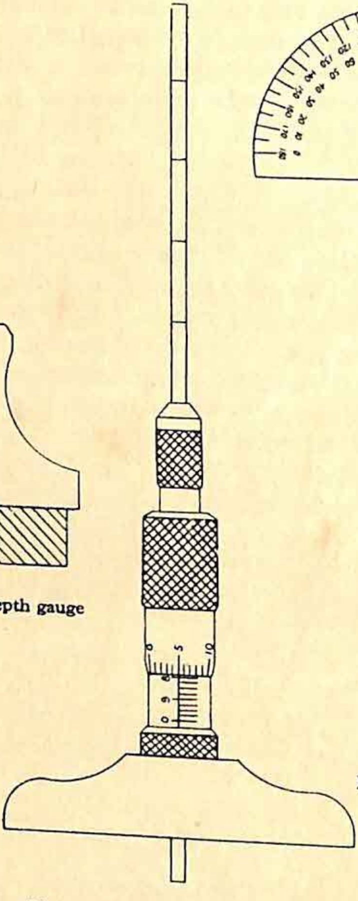


Fig. 35.—Micrometer depth gauge

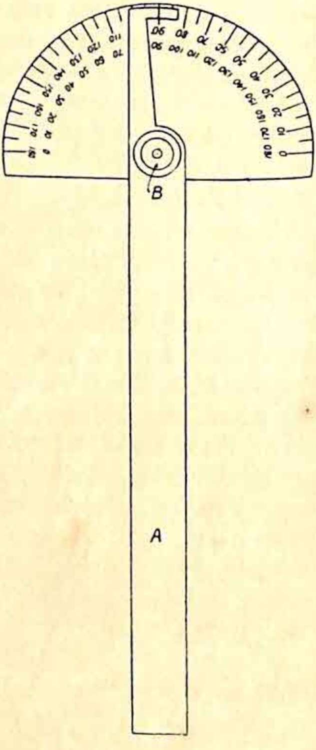


Fig. 36.—Protractor

Bevel Gauges

For checking angles, laying out work, and measuring or comparing angles, the bevel gauge is indispensable. Fig. 37 (p. 32) shows a universal bevel gauge. It will be seen that the blades may be moved into almost any position to give any required angle.

Surface Gauge

The surface gauge, or, as it is sometimes called, the scribing block, is very largely used in the laying out of parts that have to be fitted or machined. It is often necessary to scribe lines at a given height from a face of the work or to test the parallelism of the work. Fig. 38 shows a surface gauge being used for this purpose.

Feeler Gauge

The feeler gauge (fig. 39) is used for measuring the fit of surfaces which should bed together closely. It consists of a number of steel blades of varying thickness, generally ranging from ·001 in. to ·012 in. It may be found that when two machined surfaces are placed together there is an error between the two faces. By the use of the feeler gauge, this error may be measured.

Screw-pitch Gauges

Screw-pitch gauges (fig. 40) are used for testing the pitch of screw-threads. They consist of a number of blades which are cut to a given pitch. They are made to test all the standard screw-threads at present in use.

Radius Gauges

These gauges are found useful for testing work such as the collar radius of a shaft. They are made of steel blades each with a different radius, varying from $\frac{1}{64}$ in. to $\frac{1}{2}$ in. The gauges are made for internal and external work. Fig. 41 (p. 34) shows how they are used.

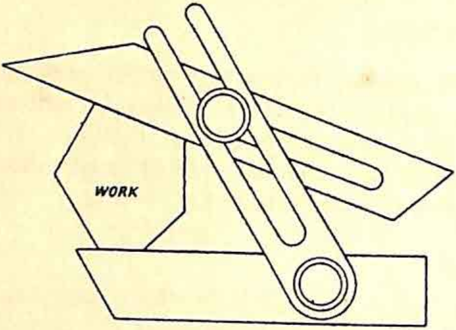


Fig. 37.—Universal bevel gauge

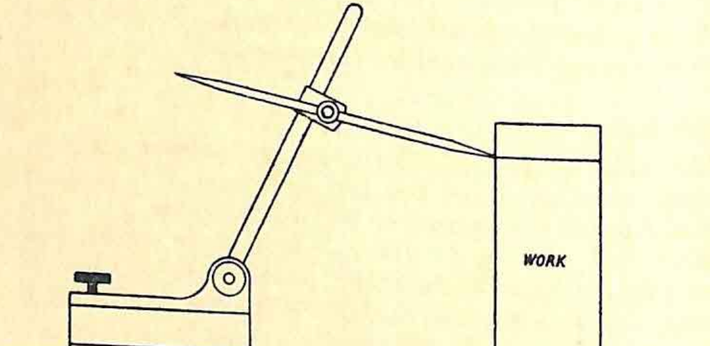
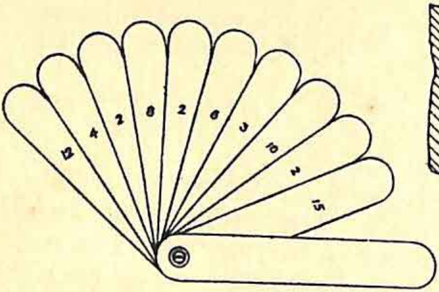


Fig. 38.—Surface gauge



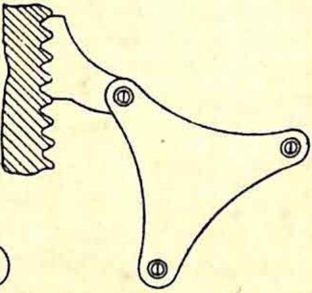


Fig. 39.—Feeler gauge

Fig. 40.—Screw-pitch gauge

Test Dial Indicator

The dial indicator, thanks to its ability to test the error of machined parts to $\frac{1}{1000}$ in., is almost indispensable for precision work. The contact point (fig. 42, p. 34) is passed over the work and this moves the needle to the amount of error. Each small division on the dial measures $\frac{1}{1000}$ in. Hence if the needle moves to 10 on the dial, the error is $\frac{10}{1000}$ in. or ·010 in. One complete revolution of the needle corresponds to $\frac{100}{1000}$ in. or ·1 in. The dial indicator is simple, reliable and very sensitive.

TABLE OF DECIMAL EQUIVALENTS

8ths, 16ths, 32nds, and 64ths of an inch

8ths	$\frac{9}{16}$ = ·5625	$\frac{17}{32}$ = ·5312	$\frac{9}{64}$ = ·1406	$\frac{37}{64}$ = ·5781
$\frac{1}{8}$ = ·125	$\frac{11}{16}$ = ·6875	$\frac{19}{32}$ = ·5937	$\frac{11}{64}$ = ·1718	$\frac{39}{64}$ = ·6093
$\frac{1}{4}$ = ·250	$\frac{13}{16}$ = ·8125	$\frac{21}{32}$ = ·6562	$\frac{13}{64}$ = ·2031	$\frac{41}{64}$ = ·6406
$\frac{3}{8}$ = ·375	$\frac{15}{16}$ = ·9375	$\frac{23}{32}$ = ·7187	$\frac{15}{64}$ = ·2343	$\frac{43}{64}$ = ·6718
$\frac{1}{2}$ = ·500		$\frac{25}{32}$ = ·7812	$\frac{17}{64}$ = ·2656	$\frac{45}{64}$ = ·7031
$\frac{5}{8}$ = ·625	**32nds**	$\frac{27}{32}$ = ·8437	$\frac{19}{64}$ = ·2968	$\frac{47}{64}$ = ·7343
$\frac{3}{4}$ = ·750	$\frac{1}{32}$ = ·0312	$\frac{29}{32}$ = ·9062	$\frac{21}{64}$ = ·3281	$\frac{49}{64}$ = ·7656
$\frac{7}{8}$ = ·875	$\frac{3}{32}$ = ·0937	$\frac{31}{32}$ = ·9687	$\frac{23}{64}$ = ·3593	$\frac{51}{64}$ = ·7968
	$\frac{5}{32}$ = ·1562		$\frac{25}{64}$ = ·3906	$\frac{53}{64}$ = ·8281
16ths	$\frac{7}{32}$ = ·2187	**64ths**	$\frac{27}{64}$ = ·4218	$\frac{55}{64}$ = ·8593
$\frac{1}{16}$ = ·0625	$\frac{9}{32}$ = ·2812	$\frac{1}{64}$ = ·0156	$\frac{29}{64}$ = ·4531	$\frac{57}{64}$ = ·8906
$\frac{3}{16}$ = ·1875	$\frac{11}{32}$ = ·3437	$\frac{3}{64}$ = ·0468	$\frac{31}{64}$ = ·4843	$\frac{59}{64}$ = ·9218
$\frac{5}{16}$ = ·3125	$\frac{13}{32}$ = ·4062	$\frac{5}{64}$ = ·0781	$\frac{33}{64}$ = ·5156	$\frac{61}{64}$ = ·9531
$\frac{7}{16}$ = ·4375	$\frac{15}{32}$ = ·4687	$\frac{7}{64}$ = ·1093	$\frac{35}{64}$ = ·5468	$\frac{63}{64}$ = ·9843

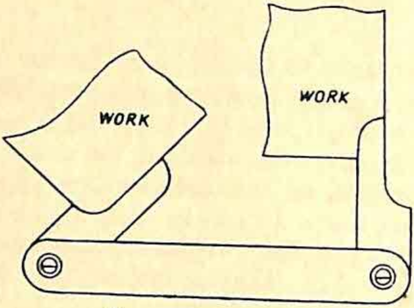


Fig. 41.—Radius gauges

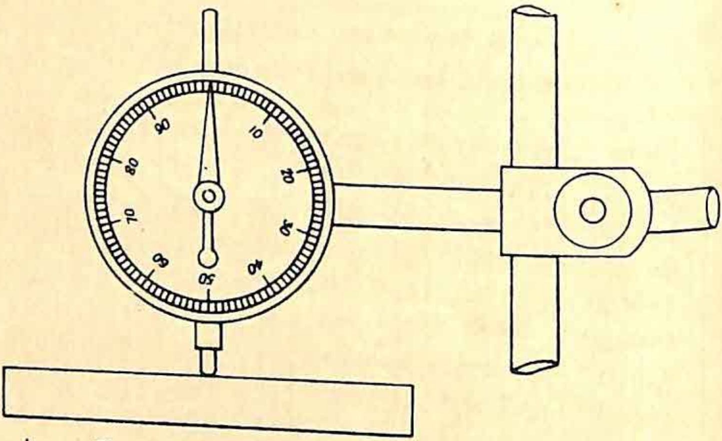


Fig. 42.—Test dial indicator

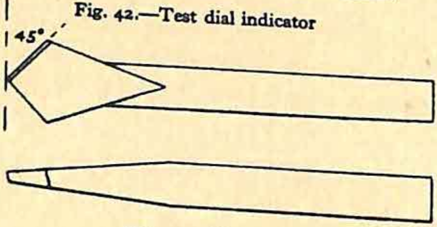


Fig. 43.—Flat drill

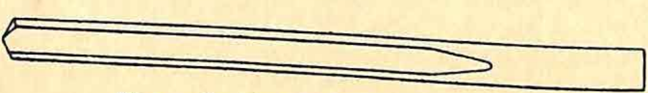


Fig. 44.—Straight fluted drill

CHAPTER V

Drills, Drilling, Reamers and Broaches

The drilling of holes is one of the most frequently repeated operations in the workshop, and it is therefore important that all details such as the cutting and clearance angles should be correct. There are three types of drills: the flat drill, the straight fluted drill, and the twist drill.

The Flat Drill

The only real advantage in using this drill lies in the fact that it is easily made. It is usually made from a piece of round steel (fig. 43) which is forged to shape and ground to size, then hardened and tempered. The cutting angle is usually about 90° and the relief or clearance at the cutting edge 3° to 8°. The cutting angle should be increased when the drill is to be used in drilling cast iron or steel. In order to cut efficiently, the cutting edges should be equal in length, otherwise the work will be thrown to one side of the drill, giving rise to a larger hole than is required. The disadvantage of this type of drill is that each time the drill is ground, its diameter is reduced. Further, it cannot be relied upon to drill a true straight hole, since the point has a tendency to run out of centre. The flat drill should never be used for important work.

The Straight Fluted Drill

The straight fluted drill (fig. 44) resembles the twist drill in sectional shape, but has no spiral twist. It is .more suitable for the softer metals, such as brass and copper, and is more easily guided than the flat drill.

The Twist Drill

For good rapid work the twist drill is now universally adopted. The important angles, which determine the result produced, must be carefully observed. The best cutting angle is 118° (fig. 45), and to obtain the correct diameter for the hole, the drill should be ground with both lips at 59° to the axis of the drill. As it is not possible to grind these correctly by hand, it should be done on a machine (twist drill grinder).

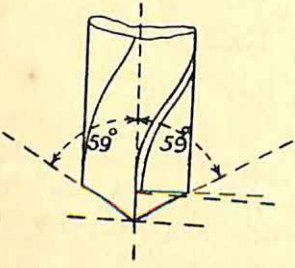


Fig. 45

In grinding, the following points require to be carefully observed:

(1) Both lips should be exactly the same length.
(2) Both lips should have the same clearance.

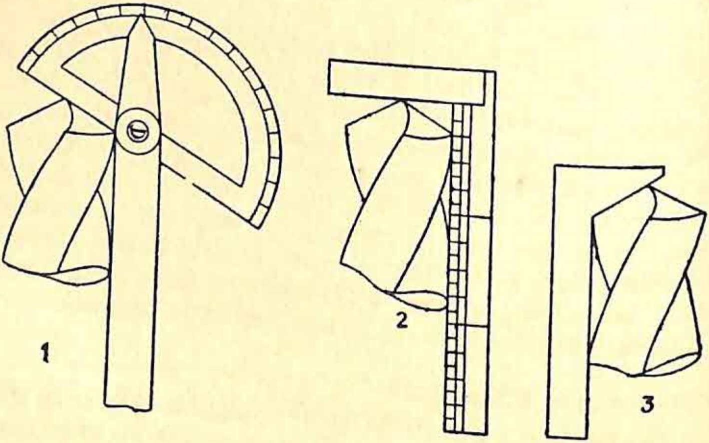


Fig. 46

(3) The lips should be equally inclined to the axis of the drill.

Fig. 46 shows three methods of testing the angle of a drill lip: (1) by a protractor; (2) by a square; (3) by a special angle gauge. If these angles are not uniform, the drill will cut a hole larger than that which is required. The result of such incorrect grinding is shown in fig. 47. It will be noticed that a great strain is thrown upon one side of the drill; in the case of small drills, this would cause them to break.

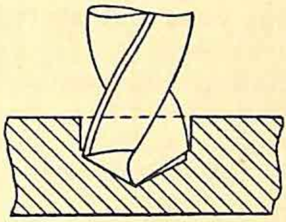


Fig. 47

To allow the drill to cut into the work, the lips must be ground obliquely, in order to obtain what is known as *relief* or *clearance*. This angle is from 3° to 6° for drilling steel, and up to 12° for drilling brass. To test the relief or clearance, the drill may be stood up against a rule, both resting on a level surface, and by turning the drill round the height of each lip can be checked. If this clearance were insufficient, the drill would not cut; rubbing and heating of the drill would result. The correct and incorrect clearances are shown in fig. 48. Fig. 49 (p. 39) shows the "land" of a twist drill, which, being ground the whole length of the drill, reduces the friction on the side of the drill. The true diameter is measured at the lands, and it will be seen

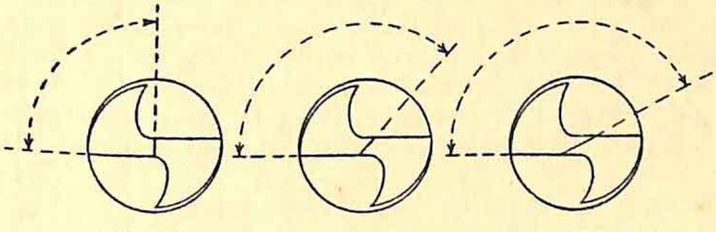


Fig. 48

that behind this, the drill is ground slightly smaller to give clearance.

There are two types of twist drills, the straight shank and the tapered shank.

The Straight Shank Drill

The straight shank drill can be held in the ordinary self-centring drill chuck (fig. 50), which in this design is tightened or released by rotating the knurled body. There are various designs of chucks, but they all have parallel jaws to hold these straight shank drills.

Taper Shanks and Sockets

By means of these drills, accurate drilling can be carried out. The spindle of the machine is bored out with a taper, and the drill has a shank with a corresponding taper. By this means the drill can be fitted directly into place, the taper effectually centring it and providing the principal driving grip. This taper is known as the Morse Standard Taper (fig. 51). As the spindle of the machine may be bored out to the large taper No. 5, tapered sleeves or sockets have to be used with small drills (fig. 52). A No. 1 socket fits all drills from $\frac{3}{16}$ to $\frac{19}{32}$ in. in diameter, No. 2 from $\frac{5}{8}$ to $\frac{29}{32}$ in., No. 3 from $\frac{13}{16}$ to $1\frac{9}{32}$ in., No. 4 from $1\frac{5}{16}$ to 2 in., and No. 5 from $2\frac{1}{16}$ to 3 in. The end of the taper is

TABLE OF MORSE TAPER SHANKS

Morse Taper No.	Taper (per foot)	Taper (per inch)
1	0·59858 inches	0·04988 inches
2	0·59941 ,,	0·04995 ,,
3	0·60235 ,,	0·05020 ,,
4	0·62326 ,,	0·05194 ,,
5	0·63151 ,,	0·05263 ,,
6	0·62565 ,,	0·05214 ,,
7	0·62400 ,,	0·05200 ,,

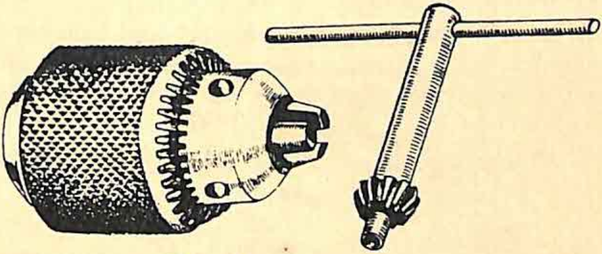


Fig. 50.

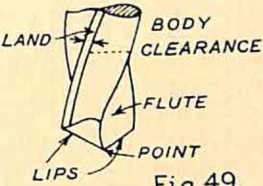


Fig. 49.

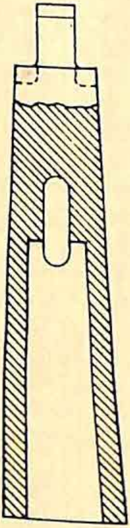


Fig. 52.

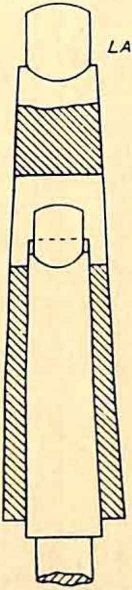


Fig. 53.

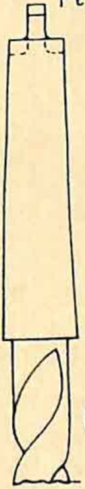


Fig. 51.

flat, and when it is inserted into a recess in the socket, the drill revolves with the socket (fig. 53, p. 39). To remove the drill a tapered key is used (fig. 54, p. 42).

Morse drills are denoted by sizes, letters and numbers, as well as by fractions. As the letter and number drills are not so well known, their sizes are given in the following list.

TABLE OF MORSE TWIST DRILLS
LETTER AND NUMBER SIZES

Description	Size	Description	Size	Description	Size	Description	Size
Letter		No.		No.		No.	
Z	·4130	1	·2280	28	·1405	55	·0520
Y	·4040	2	·2210	29	·1360	56	·0465
X	·3970	3	·2130	30	·1285	57	·0430
W	·3860	4	·2090	31	·1200	58	·0420
V	·3770	5	·2055	32	·1160	59	·0410
U	·3680	6	·2040	33	·1130	60	·0400
T	·3580	7	·2010	34	·1110	61	·0390
S	·3480	8	·1990	35	·1100	62	·0380
R	·3390	9	·1960	36	·1065	63	·0370
Q	·3320	10	·1935	37	·1040	64	·0360
P	·3230	11	·1910	38	·1015	65	·0350
O	·3160	12	·1890	39	·0995	66	·0330
N	·3020	13	·1850	40	·0980	67	·0320
M	·2950	14	·1820	41	·0960	68	·0310
L	·2900	15	·1800	42	·0935	69	·0292
K	·2810	16	·1770	43	·0890	70	·0280
J	·2770	17	·1730	44	·0860	71	0·260
I	·2720	18	·1695	45	·0820	72	·0250
H	·2660	19	·1660	46	·0810	73	·0240
G	·2610	20	·1610	47	·0785	74	·0225
F	·2570	21	·1590	48	·0760	75	·0210
E	·2500	22	·1570	49	·0730	76	·0200
D	·2460	23	·1540	50	·0700	77	·0180
C	·2420	24	·1520	51	·0670	78	·0160
B	·2380	25	·1495	52	·0635	79	·0145
A	·2340	26	·1470	53	·0595	80	·0135
		27	·1440	54	·0550		

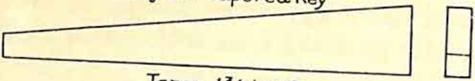
In drilling small holes ranging from $\frac{1}{16}$ to $\frac{1}{4}$ in. in diameter, better results are obtained when the drill is driven at a high speed. The speed for drills varies considerably, there being no hard-and-fast rule, but the following table of speeds is recommended for ordinary work with carbon steel drills.

SPEEDS OF TWIST DRILLS
(CARBON STEEL)

Diam. Ins.	Revs. per Minute			Diam., Ins.	Revs. per Minute		
	Wrought Iron and Steel	Cast Iron	Brass		Wrought Iron and Steel	Cast Iron	Brass
$\frac{1}{16}$	1833	2320	3667	$1\frac{1}{4}$	67	107	183
$\frac{1}{8}$	917	1160	1833	$1\frac{5}{16}$	64	102	175
$\frac{3}{16}$	611	773	1222	$1\frac{3}{8}$	61	97	167
$\frac{1}{4}$	458	580	917	$1\frac{7}{16}$	58	93	159
$\frac{5}{16}$	342	465	733	$1\frac{1}{2}$	56	89	153
$\frac{3}{8}$	285	386	611	$1\frac{9}{16}$	54	86	147
$\frac{7}{16}$	244	331	524	$1\frac{5}{8}$	52	82	141
$\frac{1}{2}$	214	290	458	$1\frac{11}{16}$	50	79	136
$\frac{9}{16}$	176	238	407	$1\frac{3}{4}$	48	76	131
$\frac{5}{8}$	159	214	367	$1\frac{7}{8}$	45	71	122
$\frac{11}{16}$	144	194	333	2	42	67	115
$\frac{3}{4}$	132	178	306	$2\frac{1}{8}$	40	63	108
$\frac{13}{16}$	112	165	282	$2\frac{1}{4}$	38	59	102
$\frac{7}{8}$	105	153	262	$2\frac{3}{8}$	36	56	96
$\frac{15}{16}$	98	143	244	$2\frac{1}{2}$	34	53	92
1	90	134	229	$2\frac{5}{8}$	32	51	87
$1\frac{1}{16}$	80	126	216	$2\frac{3}{4}$	30	49	83
$1\frac{1}{8}$	75	119	204	$2\frac{7}{8}$	28	47	80
$1\frac{3}{16}$	71	113	193	3	26	45	76

When drilling a hole, it is usual to mark the centre of the required hole with a centre-punch (fig. 55) which has

Fig. 54. Tapered Key



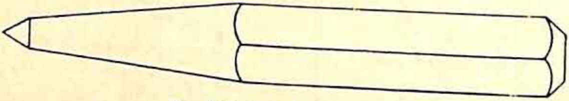


Fig. 55. Centre Punch

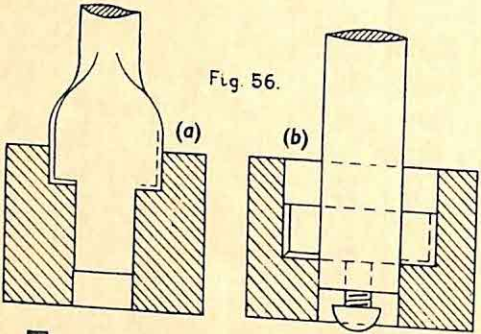


Fig. 56.

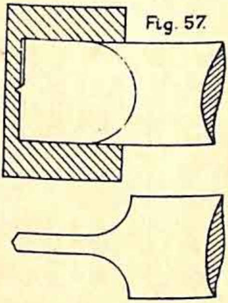


Fig. 57

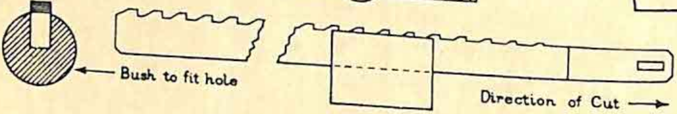


Fig. 58. Keeway Broach

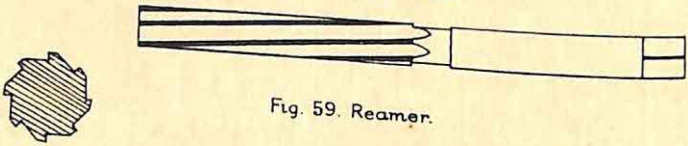


Fig. 59. Reamer.

a hardened point. This is intended to guide the drill when it commences to cut; in drilling larger holes, however, this would not be sufficient, and it is usual to begin by drilling a very small hole, called a " pilot " hole.

Having dealt with ordinary drilling, we have now to consider the drilling of special holes, such as those required when counter-boring for cheese-headed screws, and flat bottomed holes. For counter-boring or recessing, a type of pin-drill is used as shown in fig. 56*a*. The guide pin of the drill should have the same diameter as the hole, while the cutting edges should correspond to the diameter of the recess. The type of pin-drill shown in fig. 56*b* is the most useful, because the blades may be fitted in various lengths for holes of different diameter.

The flat-ended drill (fig. 57) is used for drilling holes with a flat bottom, the small projecting point being necessary to keep the drill running centrally. It may also be used to square the conical bottoms of holes that have been drilled to the required depth with a twist drill.

Reamers

Holes which are not sufficiently accurate after drilling are usually finished with a reamer. It is usual to drill a hole a little smaller than is required, and then the use of the reamer produces a true and accurate hole. Fig. 59 shows a plain spiral fluted reamer for general use. Tapered reamers are largely used for reaming parallel holes to suit taper pins or morse tapers.

Broaches

Broaches are primarily used for making holes which are not round. First a hole is drilled, then the broach is pushed or pulled through it. The teeth on the broach are progressively larger until the last few teeth are the size of the finished hole.

CHAPTER VI

Screw-threads

Until the year 1841 every manufacturer of machinery used his own shapes and sizes of screw-threads. This caused great inconvenience, for when a bolt or screwed part of a machine gave way through wear or breakage, a new part had to be made. In 1841 Sir Joseph Whitworth proposed a standard system of screw-threads, and this was adopted in Britain for nuts and bolts and all the more important parts of machines. It is known as the British Whitworth Standard (B.W.S.). The following is a table of Whitworth standard threads:

BRITISH WHITWORTH STANDARD

Size	Pitch T.P.I.	Tapping Drill	Size	Pitch T.P.I.	Tapping Drill	Size	Pitch T.P.I.	Tapping Drill
$\frac{1}{16}''$	60	57	$\frac{11}{16}''$	11	$\frac{37}{64}$	$1\frac{1}{2}''$	6	$1\frac{19}{64}$
$\frac{3}{32}''$	48	50	$\frac{3}{4}''$	10	$\frac{5}{8}$	$1\frac{5}{8}''$	5	$1\frac{3}{8}$
$\frac{1}{8}''$	40	41	$\frac{13}{16}''$	10	$\frac{11}{16}$	$1\frac{3}{4}''$	5	$1\frac{1}{2}$
$\frac{5}{32}''$	32	31	$\frac{7}{8}''$	9	$\frac{47}{64}$	$1\frac{7}{8}''$	4·5	$1\frac{19}{32}$
$\frac{3}{16}''$	24	28	$\frac{15}{16}''$	9	$\frac{51}{64}$	$2''$	4·5	$1\frac{23}{32}$
$\frac{7}{32}''$	24	18	$1''$	8	$\frac{27}{32}$	$2\frac{1}{8}''$	4·5	$1\frac{27}{32}$
$\frac{1}{4}''$	20	11	$1\frac{1}{16}''$	8	$\frac{29}{32}$	$2\frac{1}{4}''$	4	$1\frac{15}{16}$
$\frac{5}{16}''$	18	D	$1\frac{1}{8}''$	7	$\frac{61}{64}$	$2\frac{3}{8}''$	4	$2\frac{1}{16}$
$\frac{3}{8}''$	16	N	$1\frac{3}{16}''$	7	$1\frac{1}{64}$	$2\frac{1}{2}''$	4	$2\frac{3}{16}$
$\frac{7}{16}''$	14	S	$1\frac{1}{4}''$	7	$1\frac{5}{64}$	$2\frac{5}{8}''$	4	$2\frac{15}{64}$
$\frac{1}{2}''$	12	X	$1\frac{5}{16}''$	7	$1\frac{9}{64}$	$2\frac{3}{4}''$	3·5	$2\frac{25}{64}$
$\frac{9}{16}''$	12	$\frac{15}{32}$	$1\frac{3}{8}''$	6	$1\frac{11}{64}$	$2\frac{7}{8}''$	3·5	$2\frac{33}{64}$
$\frac{5}{8}''$	11	$\frac{33}{64}$	$1\frac{7}{16}''$	6	$1\frac{15}{64}$	$3''$	3·5	$2\frac{41}{64}$

The Whitworth thread (fig. 60) is triangular in section, the angle being 55°, and one-sixth of the height is rounded off at the top and bottom of the thread to a radius of ·137 of the pitch, in order to reduce the risk of damage to the thread. Owing to its depth and coarse pitch, the Whitworth thread is unsuitable for small work; the Engineering Standards Committee have therefore recommended other threads for this purpose.

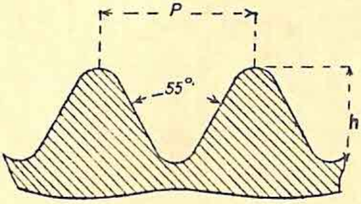


Fig. 60.—Whitworth thread
P = Pitch. $h = 0{\cdot}6403$ P.

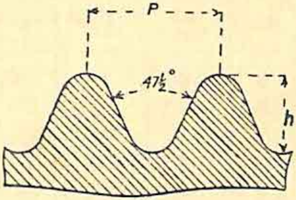


Fig. 61.—B.A. thread

The British Standard Fine Screw-thread (B.S.F.) has the same angle as the Whitworth, but, as will be seen from the following table, it has a finer pitch.

British Standard Fine (B.S.F.)

Size	Pitch T.P.I.	Tapping Drill	Size	Pitch T.P.I.	Tapping Drill	Size	Pitch T.P.I.	Tapping Drill
$\frac{7}{32}''$	28	16	$\frac{11}{16}''$	14	$\frac{39}{64}$	$1\frac{5}{8}''$	8	$1\frac{15}{32}$
$\frac{1}{4}''$	26	6	$\frac{3}{4}''$	12	$\frac{21}{32}$	$1\frac{3}{4}''$	7	$1\frac{37}{64}$
$\frac{9}{32}''$	26	B	$\frac{13}{16}''$	12	$\frac{23}{32}$	$1\frac{7}{8}''$	7	$1\frac{45}{64}$
$\frac{5}{16}''$	22	F	$\frac{7}{8}''$	11	$\frac{49}{64}$	$2''$	7	$1\frac{53}{64}$
$\frac{3}{8}''$	20	O	$1''$	10	$\frac{7}{8}$	$2\frac{1}{4}''$	6	$2\frac{3}{64}$
$\frac{7}{16}''$	18	U	$1\frac{1}{8}''$	9	$\frac{63}{64}$	$2\frac{1}{2}''$	6	$2\frac{19}{64}$
$\frac{1}{2}''$	16	$\frac{27}{64}$	$1\frac{1}{4}''$	9	$1\frac{7}{64}$	$2\frac{3}{4}''$	6	$2\frac{35}{64}$
$\frac{9}{16}''$	16	$\frac{31}{64}$	$1\frac{3}{8}''$	8	$1\frac{7}{32}$	$3''$	5	$2\frac{3}{4}$
$\frac{5}{8}''$	14	$\frac{35}{64}$	$1\frac{1}{2}''$	8	$1\frac{11}{32}$			

This type of thread is used largely for machine details.

The British Association Standard Thread (B.A.) is used for all electrical and instrument work, and for small screws. The angle of the thread is 47½° and all the details are shown in fig. 61.

BRITISH ASSOCIATION (B.A.)

Size	Pitch Mm.	Tapping Drill	Size	Pitch Mm.	Tapping Drill	Size	Pitch Mm.	Tapping Drill
0	1·00	11	9	·39	53	18	·15	77
1	·90	18	10	·35	55	19	·14	$\frac{1}{64}$
2	·81	25	11	·31	56	20	·12	80
3	·73	30	12	·28	61	21	·11	—
4	·66	33	13	·25	64	22	·10	—
5	·59	39	14	·23	69	23	·09	—
6	·53	44	15	·21	71	24	·08	—
7	·48	47	16	·19	74	25	·07	—
8	·43	51	17	·17	76			

It should be noted that in the table all the dimensions are in millimetres. Unlike the Whitworth thread, which is known by its diameter, the B.A. thread is known by a number (0 to 25), each number representing a different size. For example, No. 4 B.A. has a pitch ·66 mm., and the drill for tapping is No. 33. B.A. is recommended for threads under ¼ in. in diameter and B.S.F. for threads over ¼ in.

Other British Standard Threads

The standards described above are the most important ones. There are many others in use, among which we may mention:

British Standard Pipe Thread	B.S.P.
British Standard Cycle Thread	B.S.C.
Unified Coarse and Unified Fine Threads	U.N.C. and U.N.F.

The most convenient source of information about these, as also about the standards already mentioned, is the B.S. HANDBOOK No. 2, *Workshop Practice.*

The Unified thread is a compromise between the British and American standards. It has a 60° angle, a radius at the crest and in the root, except for the thread in the nut, which has a flat crest.

Foreign Threads

The most likely of these to be met with in British practice is the American National. This standard has both a coarse and a fine thread corresponding roughly to the B.S.W. and B.S.F. threads. The thread form is as shown in fig. 62 and, being different from the Whitworth form, these threads are not interchangeable with Whitworth threads even where the sizes and pitches are the same.

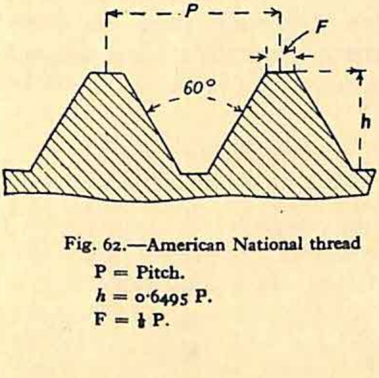


Fig. 62.—American National thread

P = Pitch.
$h = 0{\cdot}6495\,P$.
$F = \frac{1}{8}\,P$.

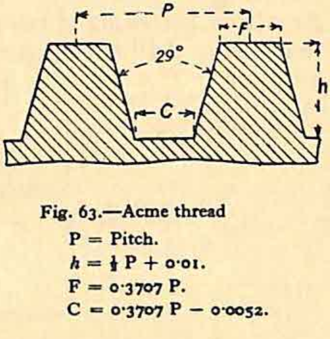


Fig. 63.—Acme thread

P = Pitch.
$h = \frac{1}{2}\,P + 0{\cdot}01$.
$F = 0{\cdot}3707\,P$.
$C = 0{\cdot}3707\,P - 0{\cdot}0052$.

Non-standard Threads

In British practice it is usual to make any non-standard V-thread of Whitworth form. At times, however, certain other forms are used, generally for operating mechanisms rather than as fastenings. Figs. 63, 64 and 65 show examples. Such threads are not fully standardized as they need not be freely interchangeable like common nuts and bolts.

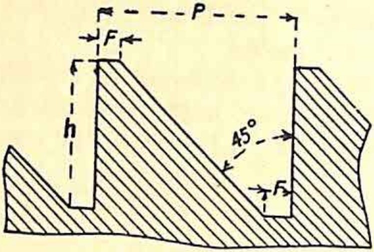


Fig. 64.—Buttress thread
P = Pitch.
$h = \frac{3}{4}P$.
$F = \frac{1}{8}P$.

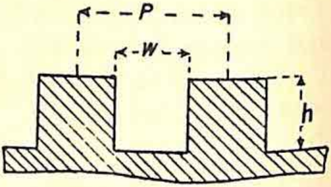


Fig. 65.—Square thread
P = Pitch.
$W = \frac{1}{2}P$.
$h = \frac{1}{2}P$.

Calculation of Tapping Sizes

The "tapping size" is the size of the hole that should be drilled before tapping. This is the same as the core diameter of the bolt. If this hole is too large an incomplete thread is formed (fig. 67), but if it is drilled too small an excessive load is put on the tap which may easily cause breakage. As a little flattening of the crests is harmless it is a common practice to drill the tapping hole a little big deliberately.

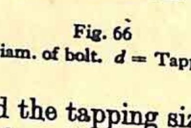


Fig. 66
D = Diam. of bolt. d = Tapping size

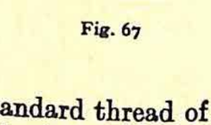


Fig. 67

To find the tapping size of a non-standard thread of Whitworth form it is necessary to work back from fig. 60. The depth of the thread $h = \frac{\cdot 64}{N}$, where N is the number of threads per inch. The core diameter is equal to the full diameter less twice the depth of thread, i.e.

$$d = D - 2h = D - \frac{1{\cdot}28}{N}.$$

As an example, suppose that a rod 3 in. in diameter, having a Whitworth thread of 12 threads per inch, has to be fitted into a cast-iron disc. The hole must be bored equal to the core diameter of the screwed bar. Fig. 68 shows the full diameter (D) and the core diameter (d).

Applying the formula,

$$d = 3 - \frac{1{\cdot}28}{12} = 2{\cdot}894 \text{ in.}$$

That is, the size of the hole to be bored is 2·894 in.

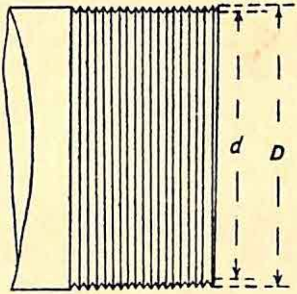


Fig. 68
D = Full diam. d = Core diam.

Accuracy of Screw-Threads.

Because of its complicated shape a screw thread cannot be made to the same accuracy as the diameter of a simple shaft. It follows that there must be a certain amount of looseness between the screw and its mating nut. There are tables which specify the amount of looseness permitted for every type of screw thread. These are of more concern to the specialist manufacturer of screws than to the general engineer. It can be accepted that ordinary taps are made to cut a little above the nominal size and mass-produced screws are made a little below the nominal size.

Bolt Heads.

Here we may mention a few of the bolts in common use (see fig. 69): (1) Hexagon head bolt; (2) Hexagon head set screw (thread the whole length of the bolt); (3) Cheese head screw; (4) Round head; (5) Square head; (6) Countersunk head; (7) Coach screw; (8) Grub screw; (9) Studs; (10) Socket head set screw; (11) Socket head cap screw; (12) Key for (10) and (11); (13) “ Phillips Recess ” countersunk head (Brit. Pat. No. 663163).

The length of bolts and screws normally *excludes* the head.

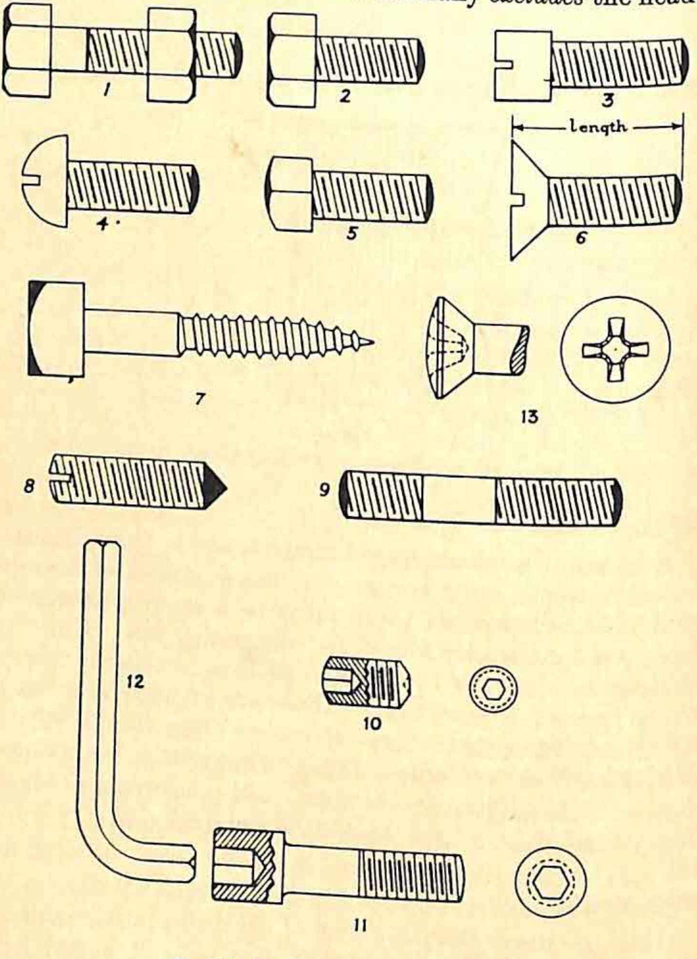


Fig. 69. Bolts in common use

CHAPTER VII

The Use of Taps, Stocks and Dies

Screw threads are divided into two classes, internal and external; threads of both classes may be successfully produced in sizes below an inch by the hand method. Taps are used for internal threads, stocks and dies for external threads.

Taps

These are usually made in sets of three: (1) Taper tap. (2) Second or intermediate tap. (3) Plug tap. (Fig. 70, p. 53).

The taper on the first is such that the small end is no larger than the tapping size of the hole. Some taper taps have at the end a small portion without a thread, equal to the tapping size of the hole. This enters the work first, and enables the tap to remain in an upright position. Fig. 71 shows a taper tap of this kind entering the work. It will be seen that the thread at the top is a full one; if this tap were to pass right through a hole, it would cut a full thread, leaving no work to be done by the other two taps.

The process of tapping a hole which does not go right through (a so-called blind-hole) is somewhat different. The taper tap is used first, until the bottom of the tap reaches the bottom of the hole, when sufficient threads are produced to enable the second tap to enter. It will be noticed that the second tap is tapered in the first few threads only. This second tap produces a thread almost the depth of the hole, and when the third or plug tap is used, the thread is completed to the bottom of the hole.

Great care should be exercised when the tap reaches the bottom of the hole, since small taps may be broken if forced too far.

To enable taps to cut well they must be properly " backed off " or relieved. Fig. 72 shows a sectional view of a three-fluted tap, backed off or relieved.

When taps are being used, plenty of oil should be applied, and great care should be taken when turning them round by means of a wrench. They should be constantly moved backward and forward, and not forced to turn. This movement relieves the cuttings from the flutes and so avoids jamming or breaking the tap.

The heads of the taps are made square to enable them to be turned by means of a tap wrench. Fig. 73 shows three forms of tap wrenches. *A* is a good adjustable type for use with any size of tap. *B* is a single-ended wrench to be used when a hole is being tapped in a corner. *C* is not recommended, as in this type of wrench the holes wear very quickly and the wrench becomes useless. The use of a tap wrench requires great care, for if the user bears too much on one side of the wrench, the tap will not enter the hole at right angles to the face of the work. This produces what is known as a " drunken thread ", and puts additional strain on the tap. After the tap has just entered the work, it is advisable to test the squareness of the tap with the face of the work, by means of a try-square.

Taps should be made of good quality cast steel and should afterwards be hardened and tempered. Owing to their hardness it is difficult to deal with taps if they are broken in the work. If the tap is broken above the work, it may be possible to remove it with a pair of pliers. If, on the other hand, the tap breaks off short in the hole, one way of removing this broken portion is by drilling. First heat the broken tap to soften or anneal it, then drill a hole slightly smaller than the tapping size. This leaves a mere shell inside, which can usually be removed very easily. The breaking of taps is frequently due to misuse, such as applying too much force, trying to twist the tap

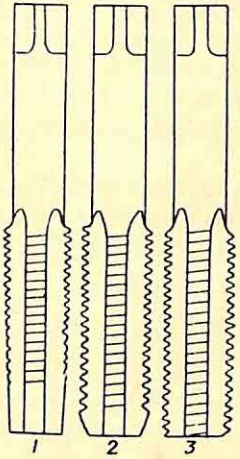


Fig. 70.—Taps

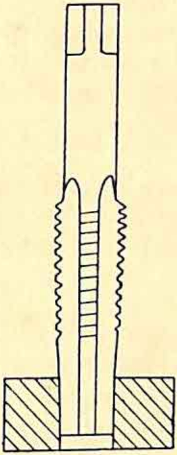


Fig. 71

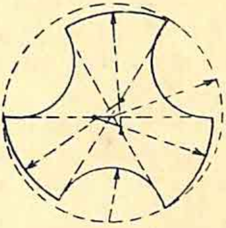


Fig. 72

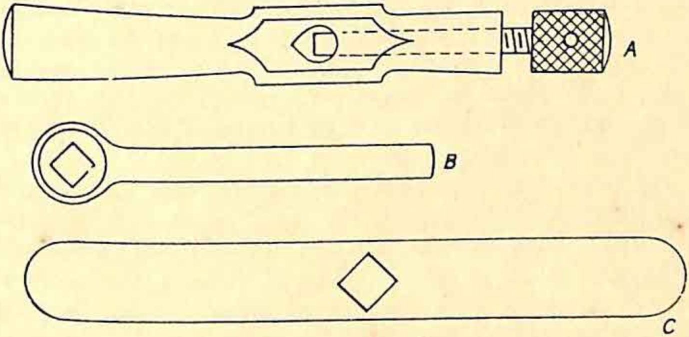


Fig. 73.—Tap wrenches

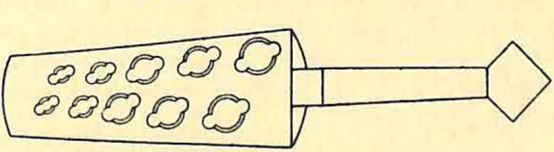


Fig. 74.—Die-plate

when it is at the bottom of a blind-hole, or endeavouring to force a blunt tap into a small hole.

Taps can easily be sharpened by grinding the cutting face of the flutes with a small emery wheel. This must be done very carefully, as repeated grinding reduces the size of the tap.

After tapping it may be found that a burr has been raised round the hole; to avoid this it is advisable to countersink the hole slightly before beginning to use the tap.

Stocks and Dies

The cutting of external threads by hand is carried out by means of various forms of stocks and dies. Fig. 74 (p. 53) shows a die-plate, consisting of a steel plate with a number of tapped holes of different sizes. It should be used only for small threads, and chiefly for soft metals. The use of these plates requires great care, as the clearance given by the two small holes on either side of the tapped hole is not great, giving a pressing rather than a cutting action, with the result that the rod may twist off in the hole. A fair amount of success may be obtained by the use of these screw plates for diameters up to $\frac{5}{16}$ in., but when a large number of threads have to be cut, it is advisable to use some other form of die.

Our choice then lies between circular dies and dies of the divided sliding type. Fig. 75 shows a very popular form of the latter. The dies are made in two halves and are fitted to the stock by V-shaped grooves, the angle of which is usually 90°. Thanks to these grooves, the dies are free to move when adjusted by the screw S. The threaded portion of each die is roughly equal to one-third of the circumference of the screw which is to be cut. A groove to form a clearance is cut in the centre of each die. Fig. 76 shows the two dies in position on the work, ready to begin cutting the thread.

The other popular type of die is the circular die. Some are solid, others are split. Fig. 77 shows these two forms. The solid die, when set in the die-holders, can only cut one

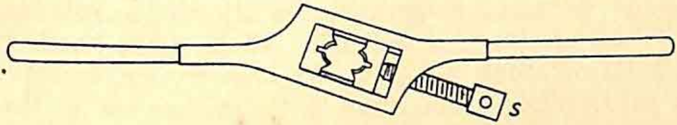


Fig. 75.—Divided sliding die.

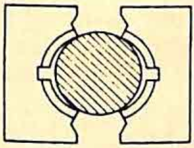


Fig. 76

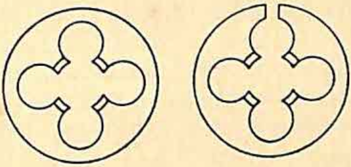


Fig. 77.—Circular dies

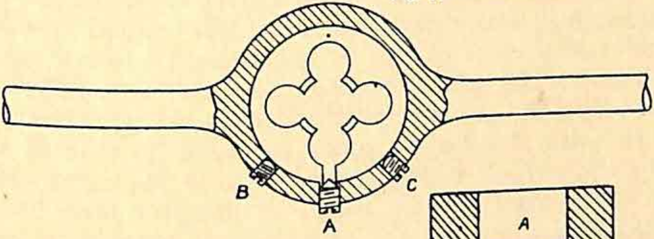


Fig. 78

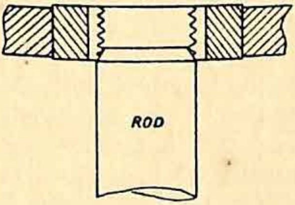


Fig. 79

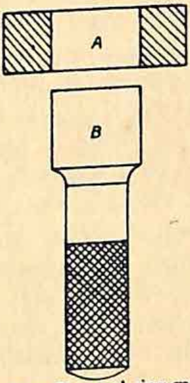


Fig. 80.—Plug and ring gauge

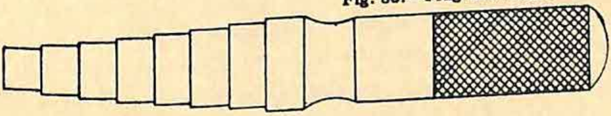


Fig. 81.—Stepped plug gauge

size, but the split die, thanks to the adjusting screws, can be opened or closed on the work. Three screws (marked A, B, C) are shown in fig. 78. To open the die, unscrew the screws B and C, and screw in A. To close the die the operation is reversed, A being unscrewed and B and C tightened.

In both types of stocks and dies, the changing of the dies for different sizes is an easy matter. It is often desirable to have a means of varying the diameter, but it is difficult to effect variations by tapping, since screws may have to be threaded to holes already tapped. This is made possible by the use of the adjustable type of stocks and dies.

Great care is necessary when the die is started, for the thread may easily be torn. It will be noticed that the first two threads of the die are tapered; this is called "lead" The risk of tearing the thread is considerably reduced if the end of the rod is also tapered (fig. 79, p. 55).

In using the die the action is similar to that of the tap and wrench. After several turns to the right, which cut the thread, the die should be turned a little to the left, as this relieves the cuttings and so prevents them from becoming jammed in the clearance slots at the centre of the die. If this is not done the thread may be completely torn off owing to these clearance slots being choked. The cut should always be taken at the top of the rod, and, by the action described above, taken the length of the required thread; then it should be brought to the top again by reversing the direction of the die. It is important that no cut should be taken on this return motion of the die.

In conclusion, we emphasize a few of the more important points to be borne in mind when using stocks and dies, and taps:

1. Always use a good lubricant.
2. Never attempt to take heavy cuts on small threads.
3. Always keep the clearance slots in the dies clear.
4. Always adopt a steady, not a jerky, movement when using dies and taps.

CHAPTER VIII

Gauges and Jigs

Gauges. Gauges are used either to test the accuracy of work directly, or to test the accuracy of other measuring tools such as micrometers. Being made usually of hardened steel and having no moving parts, they maintain their accuracy much better than the tools described in Chapter IV.

Standard Gauges. These are used mainly as standards of reference. The main types are

(1) Roller Gauges.
(2) Slip Gauges.

Roller gauges are a bi-product of the roller-bearing trade, and are supplied in sets of varying diameter. They are invaluable for checking micrometers, proving holes, and marking out work. They are not capable of measuring non-standard diameters—only proving that holes are bigger or smaller than the size of the roller.

Slip Gauges are block-shaped pieces of hardened steel which are supplied in sets so arranged that when put together end on they can be used to make up any required length. The flatness of the surface is such that when pressed together and given a twist they will stick or " wring ", and it is then possible to build up a length out of several blocks which can be handled with fair ease.

The thinnest block of most sets is ·1000 in., so that slip gauges cannot be used for very short measurements. Slip gauges are the most accurate tools used in the workshop and must be handled with great respect.

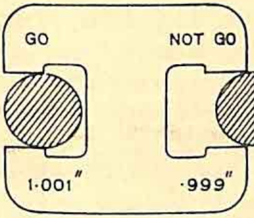
Limit Gauges

Limit gauges, now universally adopted in factories, can do what cannot possibly be done with the standard gauges just considered. They enable us to control the sizes of pieces of work to a definite amount above and below standard size. This amount is very small in the best work, perhaps $\frac{1}{10000}$ in., but is larger for less exact work. Therefore if the work is kept within these limits, it will be certain to fit its opposite part when assembled. What are known as "limits" are necessary because of the practical impossibility of making things to the exact size.

When a drawing is produced for this type of work, the dimensions are frequently marked with a plus and minus sign. For example, if the drawing were marked 2 in. ± ·001, it would indicate that the work must be kept within ·001 in. above or below two inches. To test the work with these limits is the function of the limit gauge.

It will only be possible to deal with a few of the more general types of limit gauge, as they are necessarily varied to meet the requirements of work and the accuracy needed. Fig. 82 shows a simple type of external limit gauge, by means of which it is possible to test the accuracy of the work to within $\frac{1}{1000}$ in. of the actual size required. The end marked + and "go" should pass over the work, while the end marked – and "not go" must not pass over the work. If it were found that the work entered both ends of the gauge, the work would be undersize, and if it did not enter either end of the gauge it would be oversize. Fig. 83 shows a combined "go" and "not go" plate gauge.

The adjustable gauge in fig. 84 has several advantages: (1) By adjustment of the screws, the limit can be conveniently changed to suit the work. (2) By means of the screws, the error caused by wear on the anvils can be rectified. (3) The anvils and screws can be easily replaced when worn out. The frame of the adjustable gauge is made of cast iron, and the anvils are made of hardened steel.



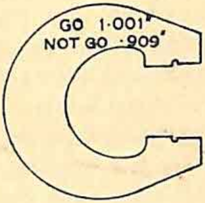


Fig. 82. EXTERNAL LIMIT GAUGES Fig. 83.

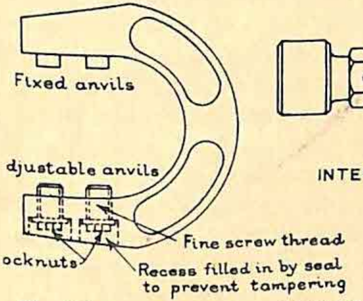


Fig. 84 ADJUSTABLE LIMIT GAUGE

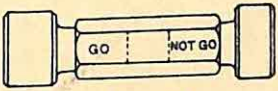
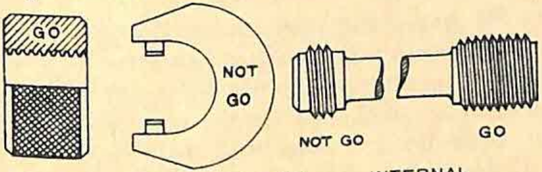


Fig. 85.

INTERNAL LIMIT GAUGE



EXTERNAL Fig. 86. INTERNAL

SCREW THREAD GAUGES.

The next gauge to be considered is the internal limit gauge shown in fig. 85 (p. 59), the drawing being marked ·425 in. ± ·001. It will be seen that the "go" end is the smaller and must enter the work, while the "not go" is the larger and must not enter the work.

The dimensions of screw threads in precision work are also controlled by limits. Fig. 86 (p. 59) shows an internal and external thread gauge. These two gauges are very largely used for testing screws produced on automatic machines. They are also used to test diameters of holes, external diameters, and internal and external threads.

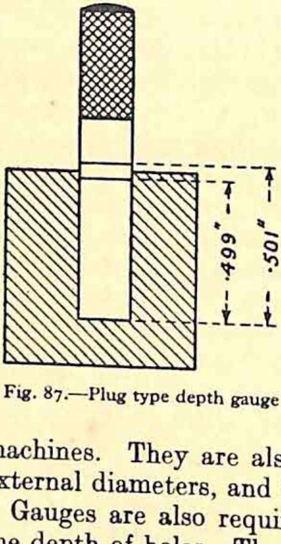


Fig. 87.—Plug type depth gauge

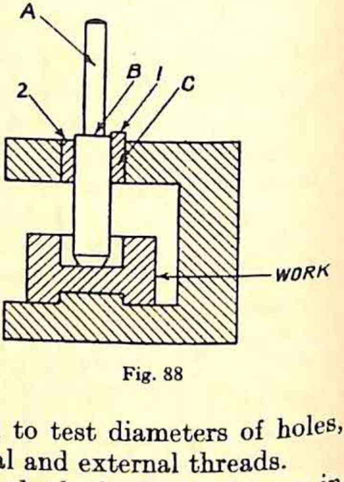


Fig. 88

Gauges are also required to check the limit of error in the depth of holes. They are usually specially designed to meet the requirements of the work in hand, and as the designs differ so much, it is only possible to mention a few which are frequently used. It should be noted that the words "high" and "low" are substituted for "go" and "not go", in this type of gauge. Fig. 87 shows a gauge of the plug type. If the depth of a hole to be tested is ·5 in. ± ·001, the low limit is ·501 in. and the high limit ·499 in. Fig. 88 shows an example of a specially designed gauge. The rod A when pressed down rests on the bottom of the hole. If the depth of the hole is within the required limits, the line B should be between the two ground faces 1 and 2 on the bush C. The difference between these two ground faces represents the limit of error allowed in the depth of the hole.

The next example is a gauge by which the depth of a hole and the height of a boss may be tested by using two rods (fig. 89, p. 62). The gauge A fits over the work B, and the high and low limits are marked on the rods R, R, while the top face of the gauge E determines the correct depth. When the rods are pressed down, the lines should be one above and one below this face.

It will now be clear that the accuracy of the results obtained by using limit gauges compensates for the cost of producing them.

In large engineering firms the work is first tested in the workshop with limit gauges, and is then transferred to the inspection department, where by means of similar gauges errors which may have passed unnoticed in the workshop are detected. It is usual to make Workshop Gauges to slightly more stringent limits than Inspection Gauges, to prevent arguments between departments.

Lapping

In the making of limit gauges, it is necessary to produce a true and accurate surface. This is done by what is known as "lapping". Plug gauges may first be turned up on a lathe. The degree of accuracy obtained depends upon the condition of the lathe; it is possible to work to within ·0005 in. Grinding machines, which are used chiefly for grinding plug gauges, reduce the diameter to within ·0003 in. of the required size. The remaining amount is removed by lapping. A cast-iron ring lap is generally used. The cast-iron ring, which is placed over the plug, is allowed to travel along the work, and by means of the screws A may be adjusted as required, as shown in fig. 91 (p. 62).

To obtain a highly polished finish, lead rings are used

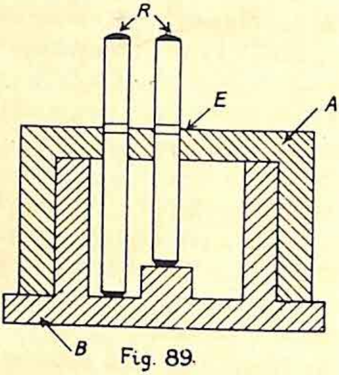


Fig. 89.

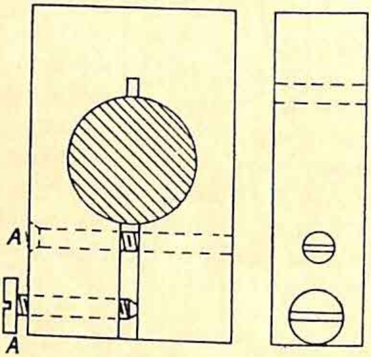


Fig. 91.

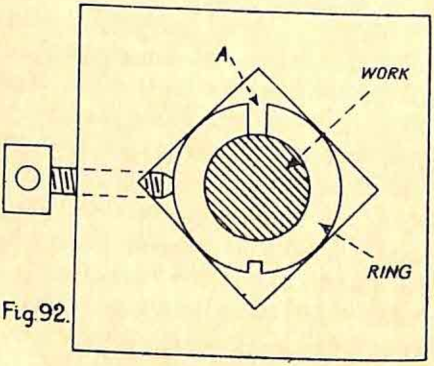


Fig. 92.

for lapping (fig. 92). A grinding compound, such as carborundum or fine emery, is placed at the opening A, and the revolving work, coming in contact with the grinding material, is reduced at a very slow rate. To obtain a very highly polished surface, rouge is often used with the lead rings.

For external limit gauges (plate gauges), the method is somewhat different. The gap, as in fig. 93 (p. 64), would have to be measured by means of a so-called "check". The gap, after being cut out and ground to within ·0003 in. of the required size, is lapped by means of an oil-stone. Lapping is highly specialized work, and it has only been possible to deal with it very briefly here.

Jigs

Jigs enable the repetition of certain drilling operations to be carried out speedily and accurately. In its simplest form, the jig may be merely a plate attached to the work, having holes corresponding in diameter and position to the holes to be drilled. With such a jig, properly located, the marking of each piece for drilling is avoided. When the jig has been made by the skilled man, cheaper labour may be employed to perform the drilling. The only error the operator can commit is to drill a hole too small or to omit one or more of the holes altogether. Fig. 94 (p. 64) shows the simplest form of jig. The thickness is usually equal to twice the diameter of the hole.

From this elementary plate form, there have developed a large variety of remarkably useful jigs, the designs of which depend upon the work. They may be, for example, of the box-type, which is used when holes are drilled on all, or nearly all, sides of the work, and the sides of the jig may be opened to allow the work to be placed inside.

It is essential to have jigs extremely rigid, so that they will not be disturbed by the thrust of the drill. The simplest jig, referred to above, is usually made of cast iron, but it quickly becomes worn and out of shape, owing to the constant passing of the drill in and out of the holes. To

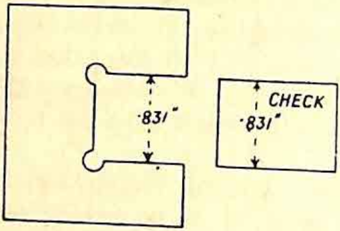


Fig. 93

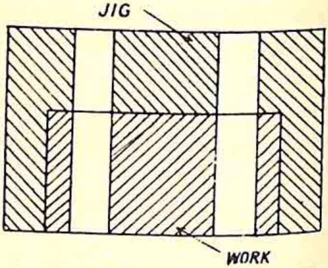


Fig. 94.—Simple jig

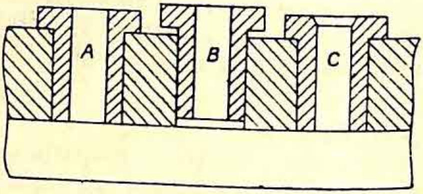


Fig. 95

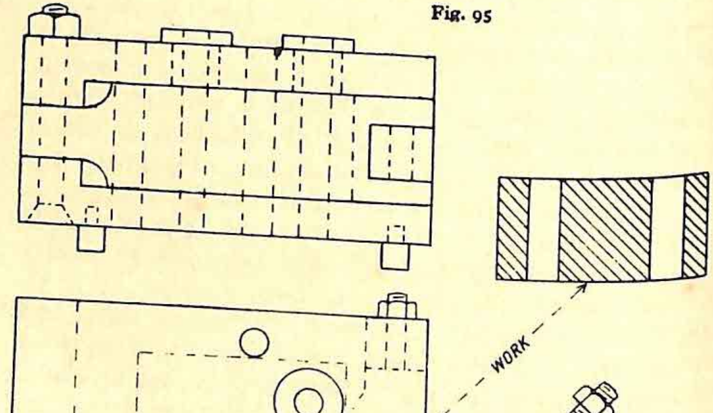


Fig. 96.—Drilling jig

prevent this, hardened steel bushes or thimbles are inserted in the holes (fig. 95). It is usual to have the bush driven down to the level of the work, shown at A, as this has the advantage of steadying the drill down to the drill point. At B the bush is not driven to the bottom of the hole, in order to allow for the clearance of chips from the drill (this only applies to large drills). At C it will be noted that the hole at the top of the bush is slightly countersunk. This is necessary in the case of very small drills, to enable them to enter the hole more directly than if the sharp edges were allowed to remain. The advantage of using bushes in jig-making is that they may be easily replaced, and this advantage is more marked in the case of the box type of jig, which is very costly to produce.

In most large firms the making of jigs and gauges is done in the tool-room, and all drawings are prepared by a special staff of draughtsmen, who are also responsible for the development of all original designs needed. As with gauges, the production of jigs is highly skilled work.

Fig. 96, which is a sketch of an actual jig, should give the reader a very clear idea of the use of a drilling jig. In addition to drilling jigs, a number of jigs or fixtures for other machining operations are in use. These are dealt with in Chap. XVIII.

CHAPTER IX

Lathe Tools, Speeds and Feeds

A thorough knowledge of the use of lathe tools, and of their various angles, is necessary before any work is commenced in a lathe. A lathe of good design, operated by ample power, contributes largely to the work, but even so, good and accurate work can only be produced when the tools are of suitable shape and size, and are ground with correct cutting and clearance angles.

Manufacture

Cutting tools are made from carbon steel, high speed steel, stellite, or tungsten carbide. Carbon steel tools are usually forged from solid bar. High speed steel tools are usually made by welding the H.S.S. tip to a mild steel shank, or, alternatively, by using a small " bit " in a toolholder.

Stellite and tungsten carbide are generally used in the form of tips brazed to a mild steel shank, but may occasionally be used as tool bits. The method of manufacture does not affect the angles to which the point of the tool must be ground. These are governed by the tool material and the material of the work being turned.

All tools should have some radius on the nose, as a dead sharp point tends to break off. For some purposes, such as machining in to shoulders, it must be quite small; for fine finishing (especially on cast iron) it must be fairly large. The choice is determined by the job and to some extent by the preference of the turner.

In fig. 97 the nose radius has been omitted for simplicity of drawing.

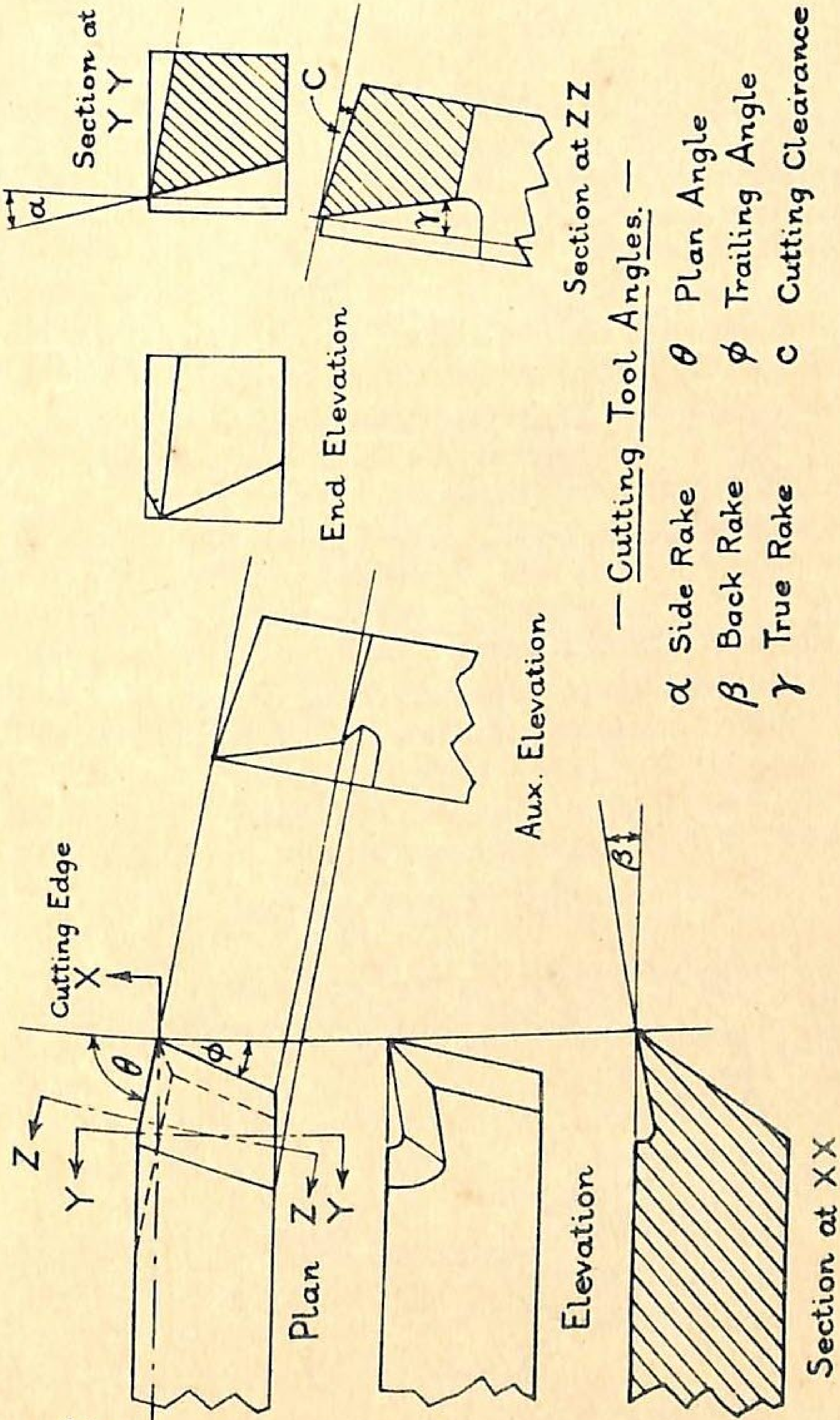

Section at Y Y
α
C
Section at Z Z
γ
End Elevation
Aux. Elevation
Cutting Edge
X
θ
φ
Z
Y
Z
Y
X
β
Plan
Elevation
Section at X X
— Cutting Tool Angles. —
α Side Rake
β Back Rake
γ True Rake
θ Plan Angle
φ Trailing Angle
c Cutting Clearance

Fig. 97.

Tool metal	High speed steel			Tungsten carbide
Work metal	Mild steel	Brass	Cast iron	Most metals
True Rake γ	20°—10°	10°—0°	15°	5°
Clearance β	5°	5°	5°	5°

Tool Angles for General Purposes.

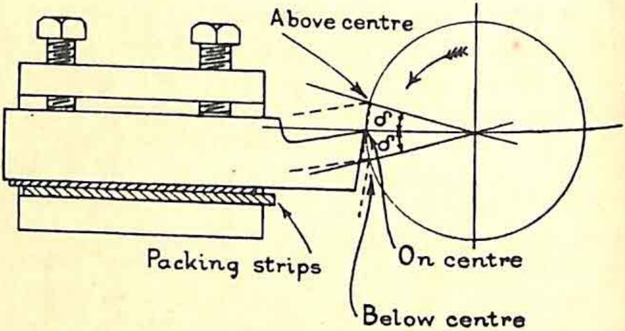


Fig. 98.
PACKING TOOL TO HEIGHT

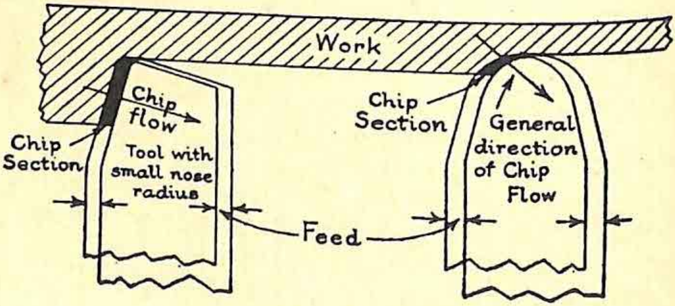


Fig. 99.
EFFECT OF NOSE RADIUS ON CHIP SECTION AND FLOW.

Angles

Fig. 97 shows the angles which go to form the cutting edge of the tool. Of these the most important, from the point of view of cutting, is the true rake, γ, and it is this that is given in the table on p. 68. It is measured in the vertical plane ZZ. This plane is perpendicular to the cutting edge as shown in the plan view. In the case of a round-nosed tool the direction of the cutting edge varies down its length, and so does the direction of ZZ (fig. 99). It follows that in general the true rake itself will vary down the length of the cutting edge. For practical purposes it is best to measure true rake in the " direction of chip flow " which is taken as perpendicular to most of the active cutting edge. As this is a very arbitrary procedure, it is always best to *specify* the angles of a tool by using side and back rake. These angles have always an exact meaning. Fig. 99 shows also how the thickness of the chip varies along the edge of a round nosed tool, being thinnest at the finished surface of the work. This in itself tends to give a good surface finish.

Clearance is essential to the working of the tool. The amount of clearance used does not vary much over the whole range of ordinary machining. The grinding and measurement of the clearance angles is very simple if the type of grinder shown in fig. 185 is used. It is simply necessary to set the tool rest to the required angle.

The choice of plan angle, θ, depends on the nature of the work. For slender work it is important to reduce " spring " as much as possible and a plan angle of about 90° ensures this. Where work is reasonably stiff it is more usual to turn with a plan angle of about 75°.

The precise value of the trailing angle is of little importance. It is merely necessary to ensure that the trailing edge is clear of the work, and 10° is quite sufficient for this purpose. The only objection to a larger trailing angle is that it weakens the point of the tool.

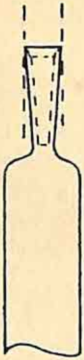


Fig. 103

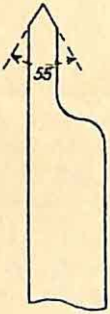


Fig. 104

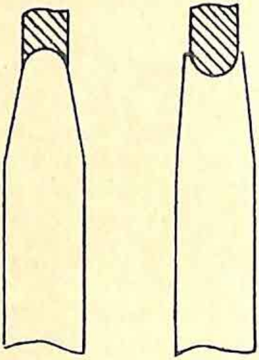


Fig. 105

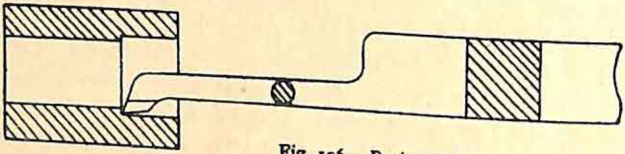


Fig. 106.—Boring tool

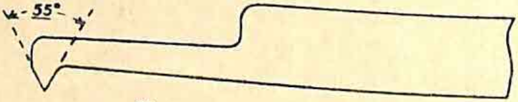


Fig. 107.—Inside screw-cutting tool.

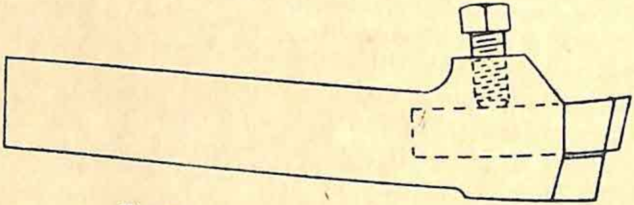


Fig. 108.—Western type of tool-holder

Setting

Fig. 98 shows the normal method of setting a lathe tool. The use of packing under the tool is important. Even if new tools start life at the correct height they will become low after repeated grinding.

On large diameter work errors in height are relatively unimportant, but on small diameters they are serious.

When a tool is set too high the clearance is reduced, which may cause rubbing. When set too low the top rake of the tool is reduced and there is a tendency for the work to ride up over the tool.

Stoning the Edge

For fine turning on steel a clean cutting edge free from scratches and serrations is desirable. This is made by lapping the tool after grinding with a fine whetstone.

Tool Holders

These are a great convenience and economy as they allow a much smaller piece of high-speed steel to be used than is otherwise possible. Some types are capable of swivelling the tool so that it may be set to the most convenient angle (fig. 110).

The weakness of all tool holders is that they need more " overhang " than is necessary for ordinary tools, and so tend to be less rigid. Pages 70 and 72 show an assortment of useful tool holders.

Fig. 111 shows a standard type of tool holder used for parting off. The blade is ready made to the correct clearance. Parting off can also be done very efficiently with tools of the type shown in fig. 114.

Boring Bars

When heavy cuts are necessary the ordinary solid forged boring tool cannot be used with success, owing to the amount of spring caused by its action. A boring bar as shown in fig. 113 (p. 72) should be used to withstand the

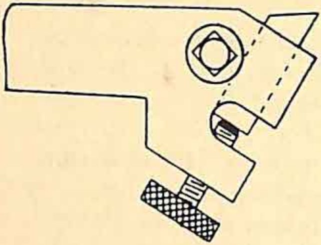


Fig. 109

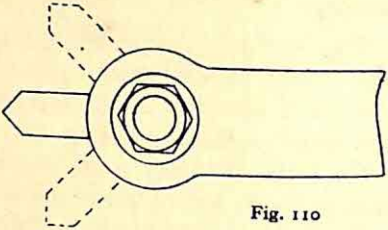


Fig. 110

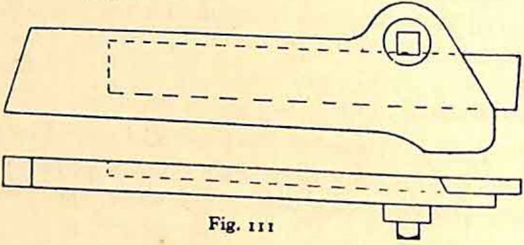


Fig. 111

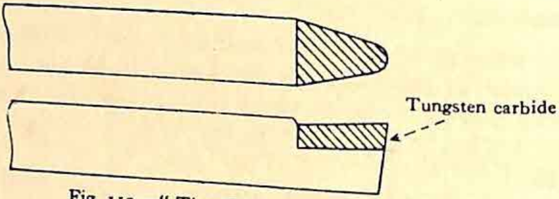


Fig. 112.—" Tipped " tool

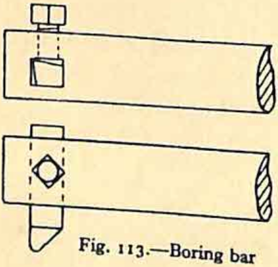


Fig. 113.—Boring bar

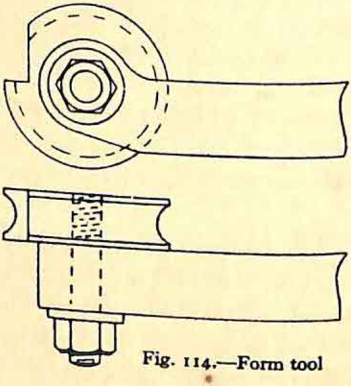


Fig. 114.—Form tool

heavy cuts; the tools may be easily changed without altering the setting of the bar.

Form Tools

The use of these tools is chiefly confined to capstan lathes and automatic machines, but form tools of a simple type can be used on an ordinary centre lathe. By means of a tool specially made to the required shape of the work, the cutting operation can be performed in one cut.

Fig. 114 gives an illustration of a form tool for small circular work. Owing to the cost of producing these tools, it is advisable to use them only when a large number of pieces of the same shape have to be produced. It will be seen from the example given, that if the tool is made circular, it can be ground when required until there is very little of it left. This will compensate for its cost.

Speeds and Feeds

On these factors the success of all cutting tools depends.

The cutting speed on a lathe is the circumference of the work multiplied by the revolutions per minute. That is,

$$\text{Cutting speed in } \textit{feet per minute} = \frac{3{\cdot}1416 \times \text{diameter (inches)} \times \text{revs. per minute}}{12}$$

The following example should make the meaning of cutting speed clear. It is required to find the cutting speed of a 4-in. bar making 85 revolutions per minute.

$$\text{Cutting speed} = \frac{85 \times 4 \times 3{\cdot}1416}{12} = 89 \text{ ft. per minute.}$$

Sometimes it is necessary to find at what speed the work should revolve in order to give a certain cutting speed. If the cutting speed is to be 50 ft. per minute, and the work is 6 in. in diameter, the number of revolutions that the bar should make in one minute is

$$\frac{50 \times 12}{3{\cdot}1416 \times 6} = \frac{600}{18{\cdot}85} = \text{roughly 32 revolutions per minute.}$$

The following is a table of cutting speeds.

AVERAGE CUTTING SPEEDS FOR H.S.S. TOOLS

Material Operated Upon	Cutting Speed (feet per minute)
Forged steel, hard ..	20–40
Mild steel	75–150
Cast iron, underneath skin	30–80
Bronzes	80–200
Free cutting brass ..	200–300
Aluminium	1000–200

The above figures refer to roughing cuts with single-point lathe tools. All finishing cuts are run slower, as also are more complicated tools such as form tools or drills.

The cutting speed in feet per minute for any given piece of work depends upon the following factors: (1) the toughness and hardness of the metal being turned; (2) the shape and size of the work; (3) the power of the lathe; (4) the composition and shape of the turning tool; (5) the amount of metal to be removed.

The harder and tougher the metal to be turned, the slower must the cutting speed be.

The feed of a lathe is the longitudinal movement of the tool when sliding, and the cross traverse in the case of facing. The most suitable feed for a lathe tool depends upon the class of metal being cut, the power of the lathe, and the amount to be removed.

Conditions vary so much that it is impossible to state any definite rule. It is best learned by practice.

CHAPTER X

Chucks and Driving Plates

The beginner should make himself thoroughly acquainted with the different types of chucks and carrier plates used for driving the work on the lathe.

The method adopted to drive the work depends on its shape. The following methods are available:

(1) Driving plate and carrier. (2) Face plate. (3) Self-centring chuck. (4) Independent jaw chuck. (5) Magnetic chuck (two types).

When it is required to work between the lathe centres, a driving plate (often known as a catch plate) and a lathe carrier should be used. Fig. 115 (p. 76) shows a common type of driving plate, which screws on to the lathe mandrel, and fig. 116 shows a common type of lathe carrier. Another type of carrier in use is known as the bent-tail carrier (fig. 117). This carrier, being bent at right angles, fits directly into the driving plate.

Fig. 118 shows how the work should appear when being driven.

By means of the face plate shown in fig. 119 work of an irregular shape may be machined. The slots in the plate allow for the adjusting and fixing of the bolts which hold the work to the face plate. Fig. 120 shows a piece of work bolted to the face plate for machining.

Self-centring Chuck

The jaws of the self-centring chuck move together, to and from the centre, so that round metal can be held centrally to the lathe spindle for turning. It is quick in

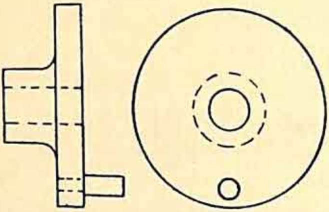


Fig. 115.—Driving plate

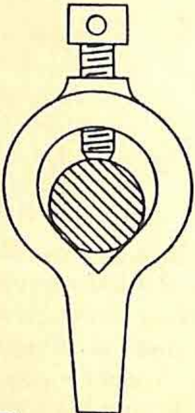


Fig. 116.—Lathe carrier

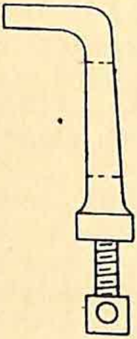


Fig. 117.—Bent-tail carrier

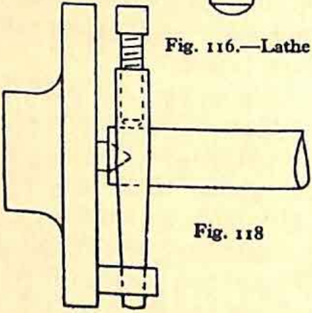


Fig. 118

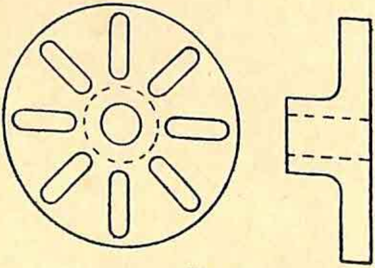


Fig. 119

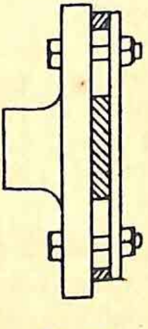


Fig. 120

use and quite adequate for many purposes, but is not to be regarded as a precision tool. In particular, accurate work cannot be taken out and replaced if it is to remain concentric. If it is necessary to remove a half-done job from the lathe, it is best to remove the chuck itself from the lathe. The locating spigot on the lathe spindle should be accurate. Fig. 121a shows a section through a self-centring chuck, with the spiral thread by which the jaws are moved. The jaws shown in this illustration enable very small rods to be held. Fig. 121b shows another set of jaws, which when fitted into the chuck enable larger round work to be held; they can also be used for holding work internally.

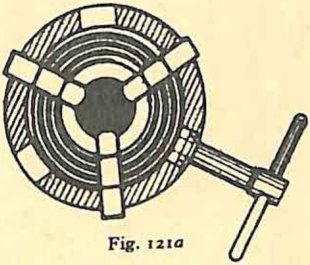


Fig. 121*a*

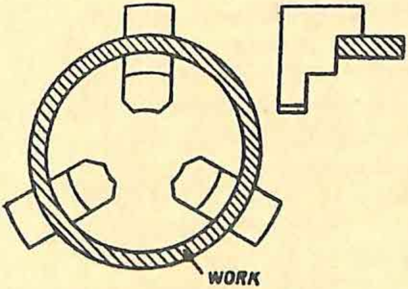


Fig. 121*b*.—Self-centring chuck

In changing these jaws some care is required in their replacement to make certain that they are equidistant from the centre. On the actual chuck, the three jaws are marked 1, 2, 3. The three slots into which the jaws fit are also marked 1, 2, 3.

The 4-Jaw Independent Chuck

Here the jaws are operated separately. Setting up to run true is then an operation done by trial and error with the aid of a Dial Gauge. This appears difficult at first but it is a skill which is quickly acquired with practice. Work may be set up by this method to any accuracy required, the out-of-truth being accurately measured by the dial gauge. Square or odd-shaped work can be held in a 4-Jaw Chuck.

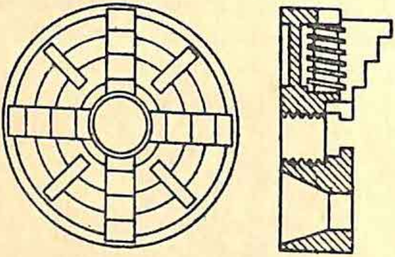


Fig. 122.—Independent jaw chuck

The independent jaws are better suited to rough forgings, castings, or lumps of metal than to bar work. If numerous pieces of work of equal diameter have to be gripped, the fixing is made easier because two of the jaws can be left unaltered, thus serving as a reference to bring each piece to a central running position.

To save time in setting, a series of circles is inscribed on the face of the chuck, and these will be found very useful when setting up work.

The same jaws can be employed for inside or outside gripping by running them out of the screws and reversing them.

Magnetic Chucks (Electric)

These chucks are used on lathes for holding work of large contact area requiring light cuts. They are magnetized by means of electro-magnets, and so possess great holding power. They are tested to 100 lb. per square inch. These chucks possess uniformity of holding power over the whole face, and, having an unlimited range of uses, they provide the simplest and quickest method of holding work.

Another advantage of these chucks is the high degree of accuracy which can be obtained, as there is no spring in the work due to clamping.

The metals which can be held magnetically are cast iron, wrought iron, malleable iron and steel. Sometimes it is found difficult to remove certain classes of work, owing to the work retaining the magnetism slightly, but this can be overcome by a demagnetizing switch supplied with the chuck. This switch is of great help in removing work having large surfaces in contact with the face of the chuck, as in such cases there are certain magnetic forces still operating after the current is switched off. The demagnetizing switch reverses the current and neutralizes these forces. Although the switch de-energizes the chuck in order to permit removal of the work, it is not intended to demagnetize the work itself; a separate demagnetizer is required for this.

Magnetic chucks of this type are used in sizes up to 24 in. in diameter. The only trouble likely to occur in the use of these chucks is failure of the electric current.

Magnetic Chucks (Non-electric)

The electro-magnetic chuck has played an enormous part in solving problems, both on the production side and in the tool-room. It provides a simple means of holding both small and large work efficiently, and in reducing the setting-up time to a minimum. The latest development is the *non-electric* magnetic chuck, which whilst retaining all these advantages, possesses additional ones which will be readily appreciated. This chuck is capable of giving all the service rendered by the electro-magnetic type with none of the disadvantages of the latter, and its exceptional holding capacity, coupled with entire freedom from breakdown, has established it as one of the most efficient of chucks.

The non-electric magnetic chuck depends on permanent magnets. All inner poles on the chuck face are of similar polarity, and are made of high permeability steel, which offers the least resistance to the magnetic flux. The top plate forms the outer poles, of opposite polarity. Parts joining the inner to the outer poles at any point complete the magnetic circuit. A half-turn of the flux control lever energizes or de-energizes the work-holding surface. This is accomplished by displacing the permanent magnet unit relative to the pole pieces with a simple eccentric movement. It will be seen, therefore, that the fixing of the work on the chuck face is effected by first putting the work in the required position and then moving the handle over from the off to the on position. Fig. 123 shows the chuck and switch lever. To release the work, the lever is reversed.

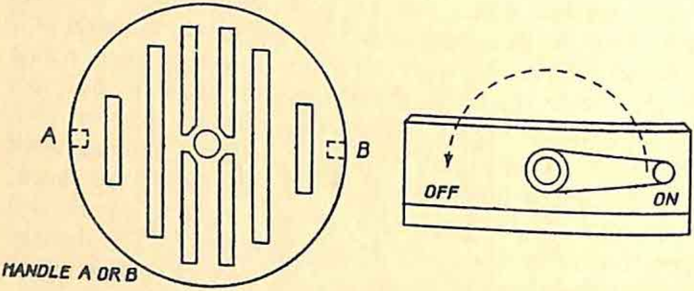


Fig. 123.—Non-electric magnetic chuck and switch

This type of chuck can be conveniently employed in other machining operations.

CHAPTER XI

Surface Plates

In the laying out of work it is usual to employ a surface plate as shown in fig. 124. The surface plate is finished on the top to a dead-flat and smooth surface. The four edges are accurately machined so that they are square with one another. The best surface plates are made of hard close-grained cast iron, to enable a good surface to be produced when machining and finishing. The main features of a surface plate are its smooth surface, and the three bearing points which support it. Underneath, the plate is stiffened by ribs, to prevent it from warping, and it should always rest on the same three supports, as the changing of these, when resting on an uneven surface, causes an irregular strain across the face of the plate. The weight of the plate also produces a strain. Fig. 125 (p. 82) is a view of the underside of the plate, showing the stiffening ribs and three bearing points A, B, C.

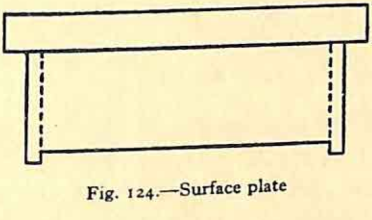
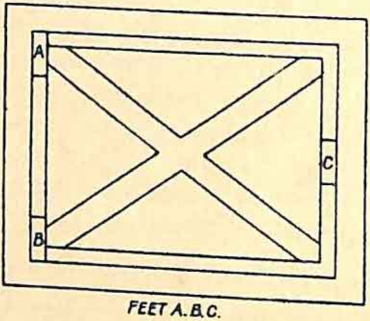


Fig. 124.—Surface plate

The surface plate is first machined, the small ones being done on the shaping machine, whilst the large ones require a planing machine. The surface produced, although approximately true, cannot be dead true, because vibrations from the machine, and the strain due to clamping or bolting down, may produce an uneven surface.

Scraping

In order to obtain a very high degree of accuracy after machining, a process called "scraping" is adopted. The tool used for this work is termed a "scraper"; fig. 126 (p. 85) illustrates a good scraper which may be made from an old file. The end is forged to the shape shown, and then made dead-hard by heating and quenching in water. The great value of the scraper lies in the fact that with it a minute amount of metal may be removed smoothly from any flat surface, and hence corrections can be made in a way that is not possible if a file is used, however fine.



FEET A.B.C.

Fig. 125

The method of testing the truth of the surface depends on the circumstances; sometimes a standard surface plate is used to compare the surfaces. A thin red-lead paste is rubbed on the standard plate, and then the plate being made is rubbed with a circular motion over the surface of the standard plate. On removal, the areas where contact has occurred are large and should be scraped carefully, then wiped and trial again made, when the number of contact points, all of which will be smaller, should be increased. These are again scraped, and the process is repeated until the spots where the red-lead is transferred occur fairly evenly over the surface; the more numerous these spots, the more accurate will be the work. If the surface is sufficiently true for the purpose desired, the scraping is stopped, but if a high degree of accuracy is required, the process is continued until very intimate contact is secured, as shown by the bright spots caused by rubbing the plates together.

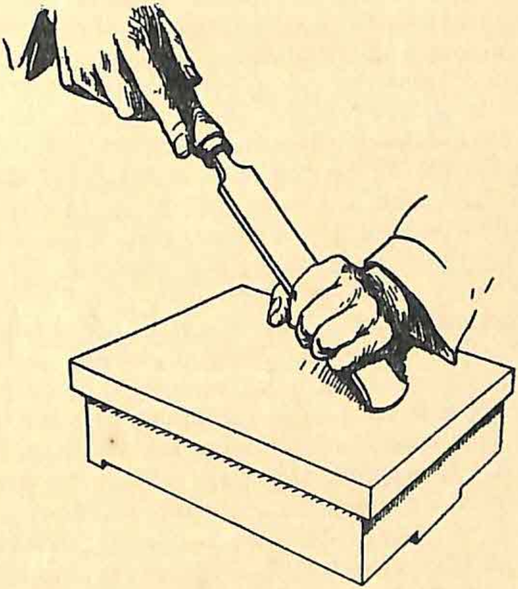


Fig. 127

At the start of the scraping process it may be found that the plates rock on each other. If this happens two false high spots will show, and care must be taken to remove metal only from the two genuine high spots.

Care should be taken in the later stages not to scrape off too much at a particular place, because this will reduce that place below the general level and the whole surface will have to be scraped down to bring it to a level with the low spots that have been carelessly produced. The ordinary flat scraper is held as shown in fig. 127 for heavy scraping, and for light finishing in a more delicate manner, using the fingers and thumb for grasping instead of the whole grip of the hand. The exact angle at which the tool is best used is soon found with a little practice. Unless the edges are kept oil-stoned keenly, it is difficult to make the tool cut at all without applying excessive pressure, when the scraping becomes uneven and uncertain.

The stoning must be done smoothly to eliminate all the burrs left by grinding, and if this is not done the scraper will leave scratches on the work. Another very important point in the use of the scraper is to take care always to move the tool with a circular motion, for if a backward and forward movement is adopted, deep grooves may be formed on the surface, and these are very difficult to remove.

The best method of producing surface plates is by using three plates, A, B, and C. These plates are machined as already explained; then after scraping A and B, cover them lightly with red-lead and rub them together to ascertain the high spots. After wiping and cleaning, the red-lead should be applied, this time only to B; too much should not be used, as this will produce marks on A, which ought not to occur. The plate B is now rubbed over A with a circular motion. This operation, together with scraping, should be continued until the plate faces make a good contact. It may be, however, that while there is perfect contact between A and B, one is slightly concave and the other convex, as shown in fig. 128. The plate C is now scraped until it is in perfect contact with A, as in fig. 129. When C and B are placed together they may appear as shown in fig. 130, and if equal quantities are scraped off C and B, they will become very nearly true. The space shown between C and B is exaggerated and actually may be no more than $\frac{1}{1000}$ in. When C and B are scraped into true planes as in fig. 131, A will have to

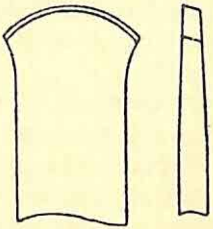


Fig. 126.—Scraper

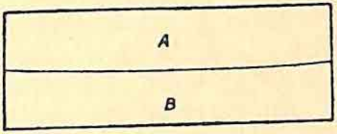


Fig. 128

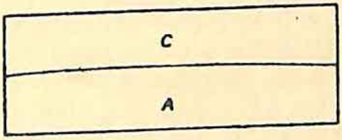


Fig. 129

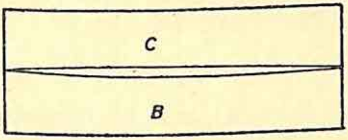


Fig. 130

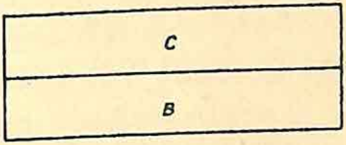


Fig. 131

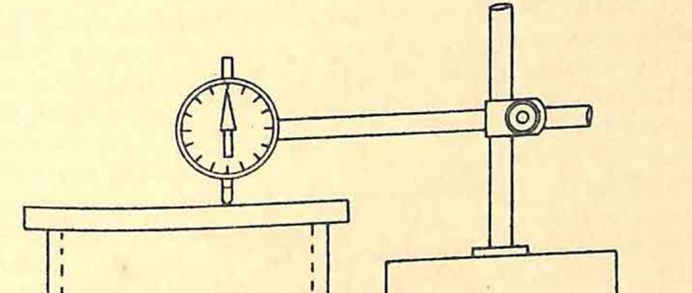


Fig. 132

be scraped true with B and C. The plate A will then become a true plane, and B and C should be applied to it in turn.

The process, in short, consists of applying A to B and C; B and C to each other; and B and C to A.

Whilst carrying out the operations described, it will greatly assist if, when the plates are nearly true, carborundum paste is placed between them. This causes a grinding action, which produces an excellent surface without scratches, and so avoids too much scraping. Care should be taken to rub the plates with a circular motion. The author has carried out this method in the workshop, and beginners have produced surface plates in this way correct to very much less than $\frac{1}{1000}$ in., and in some cases dead flat.

It is also necessary to machine and scrape the three bearing points, to make them parallel with the face.

Testing Plates

An excellent method of testing the truth of finished plates is by means of the test dial indicator shown in fig. 132 (p. 85).

Some idea of the degree of accuracy which may be produced on surfaces is conveyed by the following. It is found that if two accurate surface plates are rubbed together when perfectly dry, one will lift the other. When the plates are first rubbed together, it will be found that they slide over one another fairly easily, owing to the pressure of air between them. The effect of further rubbing is to force out the air gradually, so that the plates adhere to each other.

A test carried out recently in a works laboratory produced an amazing result. Two perfectly true surfaces 1 in. square were rubbed together, and from the lower one weights were suspended. It was found that 28 lb. were required to separate the surfaces.

It may be pointed out in conclusion that those using a scraper for the first time should experiment with an odd machined piece of cast iron, before attempting to work on a surface plate.

CHAPTER XII

Lathes and Lathe Work

General Description

The Lathe, besides being the oldest of machine tools, is regarded as the most useful of them. Its action is fascinating to beginners, and many mechanical operations can be carried out by means of it, the most common being:

1. Turning to circular form.
2. Drilling and boring.
3. Surfacing and facing.
4. Screw-cutting.

Fig. 133 shows a typical centre lathe. The main parts are the Bed, the Headstock, the Saddle and the Tailstock.

The Bed

This is the main member of the machine, and its upper surfaces are machined and scraped to form the main slide on which the other members move. The form of this slide has varied much over the years, but the purpose is always the same, namely to provide an accurate straight line movement for the sliding parts which is robust and wear resisting.

The slides of most high-quality machine tools are finally finished by the methods of scraping explained in the previous chapter. It is only by this means that a machine can be made better than the machine on which it was itself made.

Headstock

The headstock is fixed in position and carries the spindle, which in turn carries the work. The spindle is driven

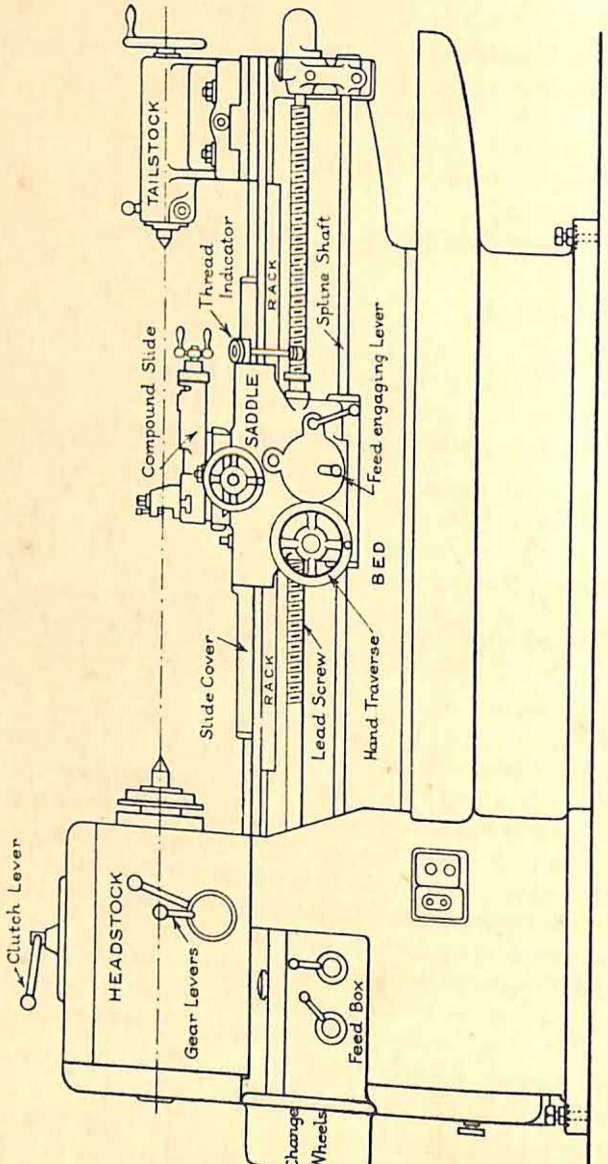
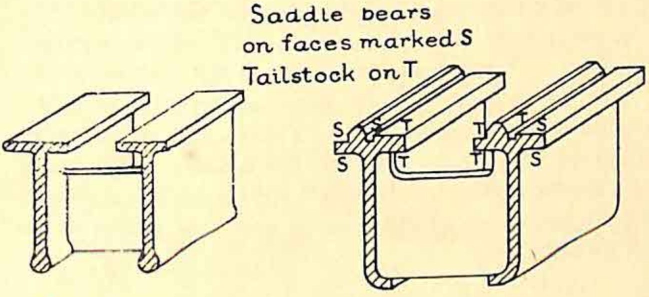
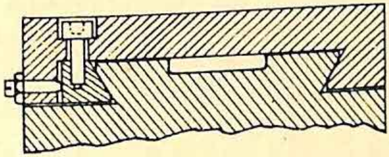


Fig. 133. SLIDING, SURFACING & SCREW CUTTING LATHE.

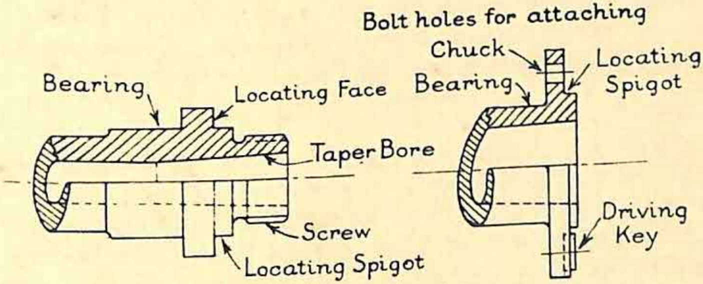


FLAT BED

INVERTED V BED



TYPICAL LATHE CROSS SLIDE



SCREWED SPINDLE NOSE

FLANGED SPINDLE NOSE

Fig. 134. LATHE DETAILS.

through gearing by a motor. The gearing permits the lathe to be used at a wide range of speeds. On older lathes the speed range is obtained by a combination of gearing and coned pulleys. The spindle itself runs in very high-quality plain or roller bearings. Plain bearings are steadier, but rollers allow a wider speed range. The spindle is hollow to accommodate long bars. The spindle nose is bored taper to hold a centre and is finished with an accurate flange and locating spigot which allows chucks and face plates to be fixed square and true.

Saddle

The purpose of the saddle is to hold the tool and move it in a controlled way as required by the job.

The saddle itself slides on the bed; on top of this is the cross slide, mounted square to the axis of the lathe. Above this again comes the compound slide which carries the tool post. The compound slide can be swivelled into any direction in the horizontal plane.

Feeds

All movements of the saddle can be made by hand. In addition Power Feeds are usually available for the longitudinal and transverse motions (sliding and surfacing).

Finally a screw-cutting motion is available from the lead screw. This motion is usually through quite separate mechanism from that used for the sliding feed.

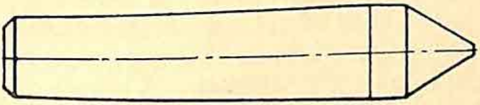
Tailstock

This is used to hold the end of the work. It slides on the bed and can be clamped in any position. The plunger has a short longitudinal travel which is worked by the hand wheel. It is capable of being adjusted sideways for turning taper work.

Dimensions of a Lathe

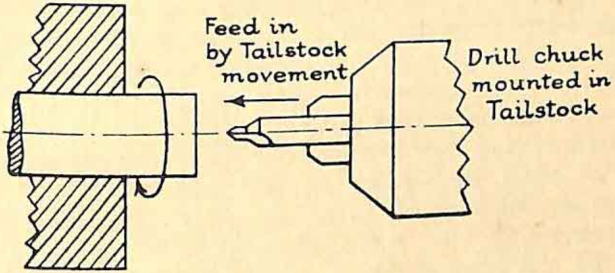
The dimensions which specify the size of a lathe are:

1. Centre Height, from the bed to the line of the centres.



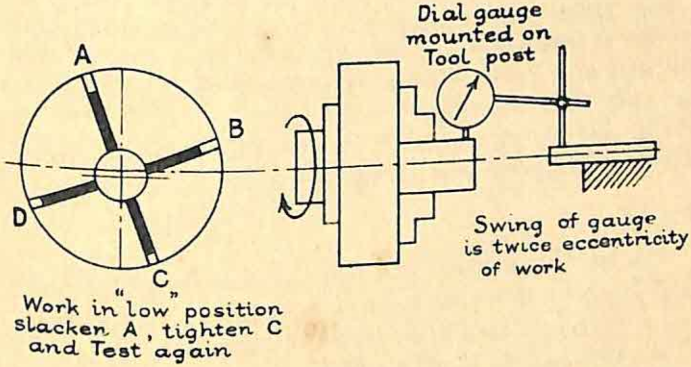
LATHE CENTRE

Fig. 135.



CENTRING BAR

Fig. 136.



TRUING WORK IN INDEPENDENT JAW CHUCK

Fig. 137.

2. Swing over Bed. This is the diameter of work which can be swung, and is usually twice the centre height.
3. Swing over Saddle. This is the largest diameter which can be turned between centres.
4. Swing in Gap (if gap is fitted).
5. Length between Centres.

Centring

Before work can be turned between centres, it is first necessary to centre and drill the ends, which have been faced up. A good method of finding the centre is by means of a vee block and surface gauge as shown in fig. 139. The vee block and surface gauge are placed on a surface plate, the bar being placed on the vee block. The ends are covered with chalk, and using the left hand, the bar is moved round; the point of the surface gauge will produce lines as shown in fig. 140. This centre must be drilled with a centre drill, the angle of which is 60° and corresponds with the lathe centre. Fig. 141 shows a centre drill, and the shape of the hole after drilling. Both ends having been centred and drilled, the rod is now ready for turning in the lathe.

Fig. 136 shows an alternative method of centring round work. It is a feature of the centre-drill that when fed into the end of a revolving bar it will drill true. This is not the case with the ordinary twist-drill.

Fig. 142 shows the work in the lathe between centres, with driving plate and carrier.

Facing

The next operation to be considered is facing. Fig. 143 (p. 95) shows three methods of facing:

1. Work held in a self-centring chuck.
2. Work bolted to a face plate.
3. Work held between centres (using right- and left-handed tools).

It is important to note the side clearance during this operation.

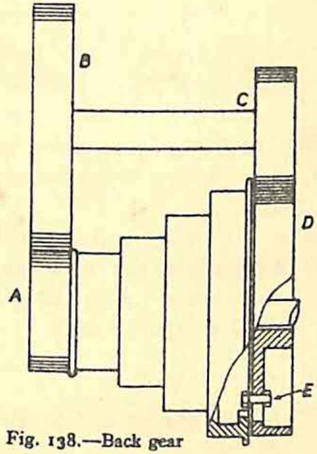


Fig. 138.—Back gear

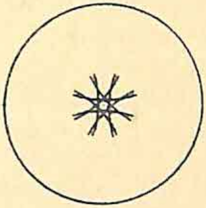


Fig. 140

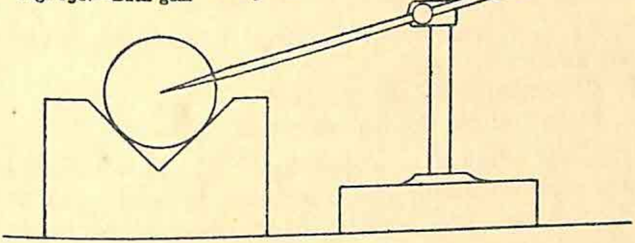


Fig. 139.—Vee block and surface gauge

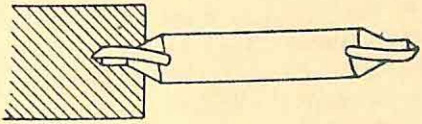


Fig. 141.—Centre drill

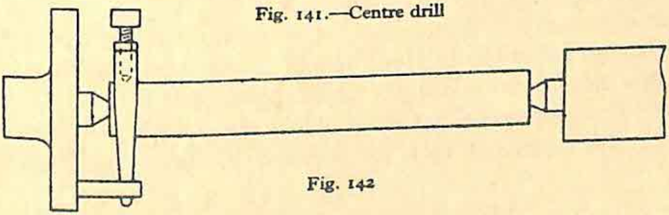


Fig. 142

Boring

Boring on the lathe from the slide rest is the method adopted to produce parallel or tapered holes, by the use of boring tools or boring bars.

The size, when boring, can be readily adjusted by manipulating the slide rest. Fig. 144 shows a sectional view of a boring tool and boring bar in use.

When boring a tapered hole, the slide rest should be set over to the required angle, which is easily done, as the slide rest is usually graduated in degrees. Fig. 145 (p. 97) shows the tool in position for boring a tapered hole.

Taper Turning

Taper turning on the lathe is a very important operation which can be carried out in several ways:

1. By a special taper turning attachment, which is fitted to some lathes.
2. By setting over the tailstock.
3. By swivelling the top slide rest.

The first method is undoubtedly the most satisfactory where it can be used. The attachment is usually graduated in degrees and taper per foot, but such attachments cannot be used for steep tapers, the maximum being about 15° to the centre line. In one attachment, shown in fig. 146 (p. 97), the top vee of the lathe bed is set over. When the nut A is released, screws B and C may be adjusted to bring the top section of the lathe bed to the correct position for the taper required, by means of the scale.

Setting over the tailstock, as in fig. 147 (p. 97), is a suitable method for turning long tapers. When the work is turned taper the full length, and the set over is x, then the difference in the diameter of the work will be $x \times 2$. To find the amount of set over, when the length of the work and the taper per inch are known, the following formula is used:

$$\text{Set over} = \frac{\text{Length of work in inches} \times \text{Taper per inch}}{2}$$

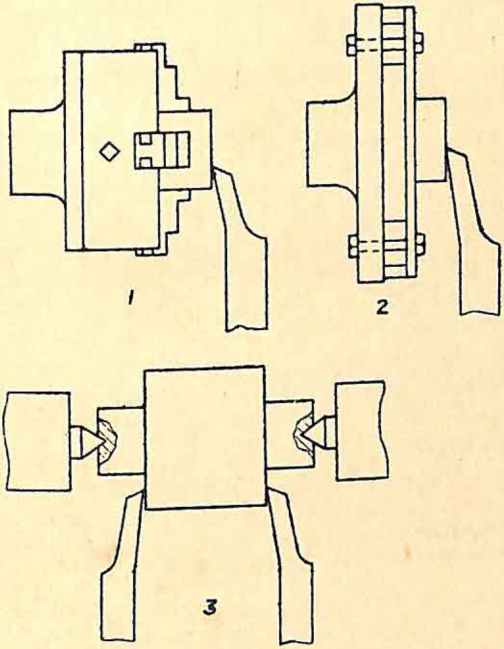


Fig. 143.—Facing

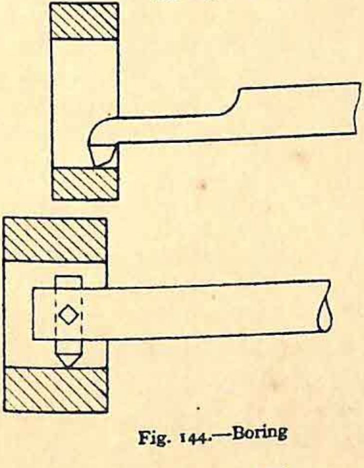


Fig. 144.—Boring

When the two diameters are known, and the work is turned taper the full length:

Set over = (Large diameter − Small diameter) ÷ 2.

Taper Turning by the Compound Slide

In lathes which have the slide-rest graduated in degrees for taper-turning purposes, it is often difficult to know at what angle to set the rest for a taper for which the dimensions only are given. For example, the taper shown in fig. 148 may be required, the sizes given being the length of the taper, and the diameters at each end. In order to set the compound slide correctly, we must either calculate or measure in some way the angle included between the sides of this tapered work. The following simple table will give the correct angle at which to set the slide-rest for a fairly wide range of tapers. The taper is given as so much per foot.

Taper per Foot in Inches	Included Angle		Angle with Centre Line	
in.	deg.	min.	deg.	min.
$\frac{1}{8}$	0	36	0	18
$\frac{1}{4}$	1	12	0	36
$\frac{5}{16}$	1	30	0	45
$\frac{3}{8}$	1	47	0	53
$\frac{7}{16}$	2	05	1	02
$\frac{1}{2}$	2	23	1	11
$\frac{3}{4}$	3	35	1	47
1	4	45	2	23
$1\frac{1}{2}$	8	20	4	10
2	9	32	4	46

If the work is dimensioned, it is an easy matter to see how much difference in diameter occurs per foot of length. For instance, if the work is 4 in. long, and the difference in diameter between the two ends is $\frac{1}{8}$ in., the taper is

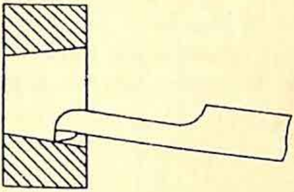


Fig. 145

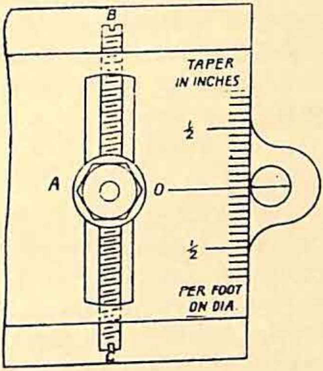


Fig. 146

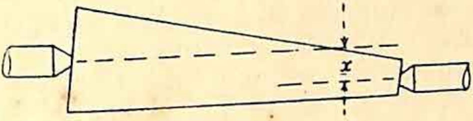


Fig. 147

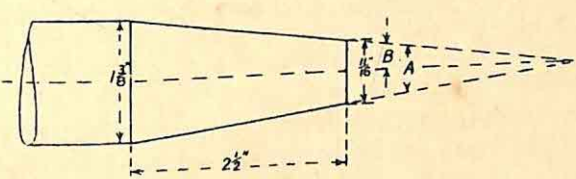


Fig. 148

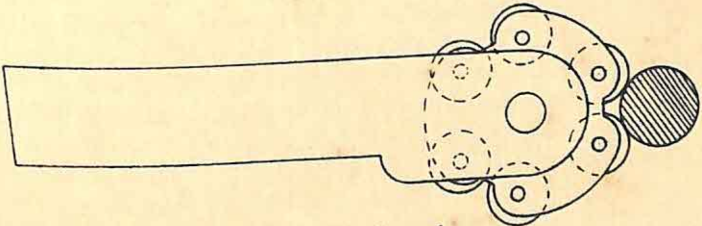


Fig. 149.—Knurling tool

$\frac{3}{8}$ in. per foot. In the second column is given the included angle (A in the illustration), and in the third the correct angle at which to set the slide-rest, that is, the angle that one side of the taper makes with the centre line, as shown at B.

Knurling

The use of the knurling tool produces a diamond-shaped pattern on circular work. This provides a grip which is particularly useful when using plug gauges. The knurling tool in fig. 149 (p. 97) is provided with three sets of wheels, coarse, medium, and fine. It will be seen from the illustration that this particular design provides a means by which the work is kept central with the revolving wheels. The tool should be moved forward until the wheels touch the revolving work, and then fed along the length required to be knurled. The tool may be fed along in either direction. The inward feed is continued until the diamond-shaped knurl is complete. The wheels should not be removed from the work until the knurling is completed. If it is found necessary to examine the work during the knurling operation, it is advisable to stop the machine with the wheels on the work.

Screw-cutting

Screw-cutting on the lathe is a process requiring much skill. The lathe must be provided with a lead-screw, in order to move the saddle, and the pitch of the lead-screw must be ascertained before any work is attempted. This will vary according to the size of the lathe; a small pitch will usually be found on a small lathe. If the pitch is $\frac{1}{8}$, this means that the thread has 8 threads per inch. A full set of gears is provided, 21 in all, the smallest having 20 teeth, and the number increasing by 5 to 120 teeth in the largest. If the lead-screw of the lathe is connected to the lathe spindle so as to revolve at the same rate, the tool fixed in the tool-post, and the lead-screw coupled to the saddle, it will be seen that the tool will cut a thread on a rod with a pitch equal to that of the lead-screw. If the lead-screw revolves at twice the speed of the lathe spindle, a screw of pitch double that of the lead-screw, or half the number of threads per inch, is produced.

The rule for the calculations of the change wheels for cutting any pitch is fairly easy, as will be seen from what follows. First find the number of threads per inch on the lead-screw of the lathe, and the number of threads per inch that have to be cut. The ratio of the speed of the lead-screw and the speed of the lathe shaft is given by the formula:

$$\frac{\text{number of threads per inch on lead-screw}}{\text{number of threads per inch to be cut}}.$$

The same ratio must be given by all the driven and driving wheels. The pitch is always given as threads per inch.

As an example, suppose we have to cut 8 threads per inch, with a lead-screw of 4 threads per inch; the ratio is $\frac{4}{8}$. This gives 4 teeth on the lathe spindle, and 8 teeth on the lead-screw, but as wheels of this size are not in the set, the size must be increased, the ratio being maintained. This can be done by multiplying each by a number which yields two gears which are in the set. For example, multiplying by 10 gives 40 and 80 as the gears to be used. It will be found, however, that when these two gears are placed in position, the distance between the lathe spindle and the lead-screw will not allow them to connect. They must therefore be connected by what is known as an "idle wheel". This idle wheel can be of any size, as it is not connected to any revolving spindle, its sole purpose being to communicate the motion of the lathe spindle to the lead-screw. When the ratio is 6 to 1 or less, the gears may be used in a so-called "single train" of gears. The lathe is provided with a quadrant on which the gears are fixed. Fig. 150 (p. 100) shows a single train of gears in position, with an idle wheel, fixed on the quadrant.

When the ratio is more than 6 to 1, it is necessary to use a "compound train" of gears.

As an example, suppose that the lead-screw has 4 threads per inch, and we have to cut 30 threads per inch. The ratio is $\frac{4}{30}$; this may be split up into two fractions, which when multiplied together give this ratio. Thus $\frac{4}{30} = \frac{2}{5} \times \frac{2}{6}$, and if wheels of these sizes were obtainable the two driving wheels would be 2 and the driven wheels 5 and 6. We now proceed as with the single train and multiply each number by 10, thus producing $\frac{20}{50} \times \frac{20}{60}$. Fig. 151 shows this compound train of gears (A, B, C, D) in position. Any compound train can be worked out this way. Another example may be given:

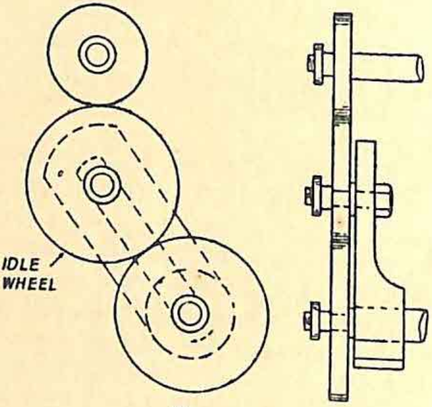


Fig. 150

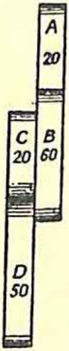


Fig. 151

Lead-screw 4, threads to be cut 48 per inch.

Ratio $= \frac{4}{48}$. $\frac{A}{B} \times \frac{C}{D}$ must equal this ratio. Now

$$\frac{4}{48} = \frac{2}{6} \times \frac{2}{8} = \frac{20}{60} \times \frac{20}{80}.$$

To test the correctness of the train of gears, multiply the numbers of teeth on all the driving wheels together, and then the numbers of teeth on all the driven wheels together. Divide the former by the latter; the result should be the ratio originally taken, that is, the number of threads on the lead-screw per inch, divided by the number of threads to be cut per inch.

For cutting right-handed threads, the lead-screw must revolve in the same direction as the lathe spindle, but for left-handed threads in the opposite direction. This can usually be done by means of a reverse gear which is provided in the drive from the spindle. If, however, the lathe is not provided with tumbler gearing, a left-handed thread can be cut by including an additional idle wheel when setting up the gears, as shown in fig. 152.

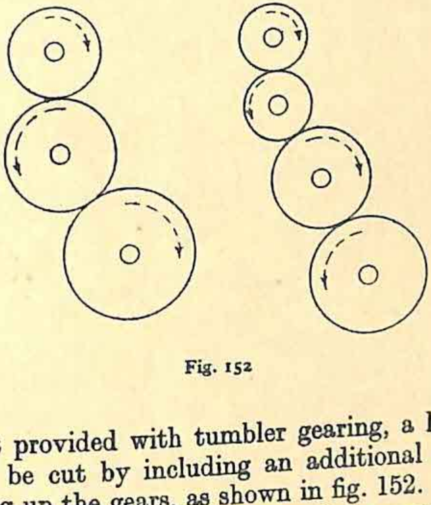


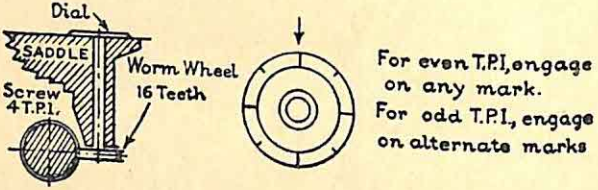
Fig. 152

When cutting a thread on a lathe, it is necessary to go over the work several times, working slightly deeper each time, until the thread is fully formed. Care must be taken that the tool follows the same path each time. This happens automatically when the number of threads per inch to be cut is an exact multiple of the T.P.I. of the lead-screw.

The "matching interval" is the name given to the shortest length which contains a whole number of threads on both the lead-screw and the thread being cut. In the simplest case this is just the pitch of the lead-screw, thus, when cutting an 8 T.P.I. thread with a 4 T.P.I. lead-screw the matching interval is ¼ in., which is one lead-screw pitch or two thread pitches.

All the methods used for "catching the thread" are devices for moving the saddle an exact number of matching intervals relative to the lead-screw. The neatest method is by the use of the Thread Indicator (fig. 153) which is built into most modern lathes. This indicator shows the movement of the saddle relative to the lead-screw.

Thus if we are cutting an 11 T.P.I. with a 4 T.P.I. lead-screw it is necessary to shift the saddle in multiples of 1 in. to go from the root of one thread to the root of a corresponding thread. This is ensured by engaging the nut only on the marks indicated. This device can be used without stopping the lathe. It fails only when a very awkward thread is to be cut, such as a metric. Here the matching interval may be very long (amounting to several turns of the indicator).



THREAD INDICATOR

Fig. 153

In such cases the only course is to reverse the lathe. It is most important to withdraw the tool before doing this.

A third method, which is similar to using the thread indicator, is to stop the lathe at a fixed spot (marking the chuck for accuracy), then traverse the saddle back a multiple of the matching interval and engage the nut.

To cut a Whitworth form thread the tool itself should be set by gauge. The in-feed is best done by the compound slide and should be oblique as shown. This allows the tool to cut on one side only, which prevents the tool digging-in, which is always a danger when screw-cutting.

The tool is first brought up to touch the work and the dial on the cross slide set to zero. The cross slide is then used only for disengaging the tool, being returned to zero at the start of each cut.

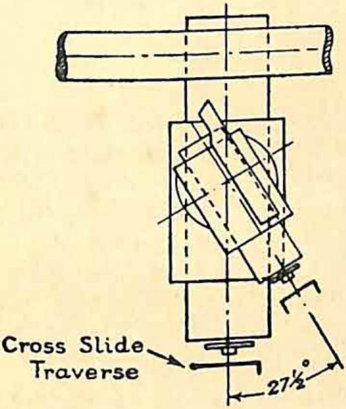


Fig. 154*a*

Oblique in-feed

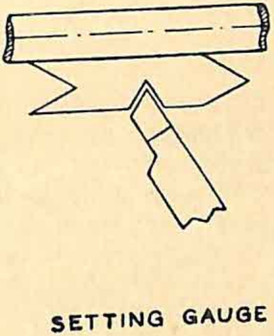


Fig. 154*b*

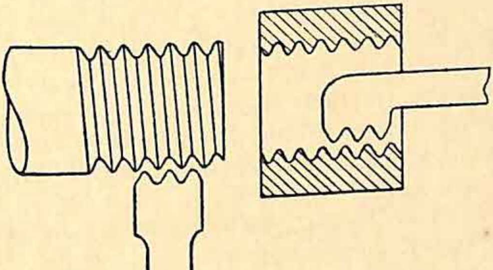


Fig. 155.—Showing "chaser"

The screw-cutting tool when cutting does not produce the radius at the top required for a Whitworth thread; this can be cut with a "chaser". Fig. 155 shows a chaser in position for external and internal threads.

CHAPTER XIII

Drilling Machines

In most machine shops many designs of drilling machines will be found, varying according to the particular type of work to be produced. The essential features are the means of rotating the drills, feeding them to the work, fixing the work, and adjusting it on the drill to the exact position.

A machine which is very common for general purpose work is the Radial Arm Drill. In the form shown in fig. 156 the main motor M_1 is situated in the Head. An auxiliary motor M_2 is used for raising and lowering the arm.

The spindle has a feeding movement which can be operated either by the handles H or by the power feed. Within the head are two gear boxes, one for the spindle drive and the other for the feed.

All drilling machine spindles are provided with some form of counter-balance, so that they will not fall down under their own weight. In most machines a clock spring is used which is strong enough to raise the spindle to the top of its movement when no feed is applied. The spindle is provided with a reverse gear so that the machine may be used for tapping as well as drilling. A depth stop is provided which will knock out the feed at any required depth. This is invaluable for repetition work. Locks are provided to all the movements of the machine, and when doing heavy work it is necessary to use them, otherwise the looseness of the machine will give inaccurate work. For convenience these locks are all controlled by one lever on the drilling head. The pit shown in the floor beside the machine is a great convenience for drilling the ends of long objects, especially pipe flanges. The work is clamped to the side of the table and the tail end hangs down into the pit.

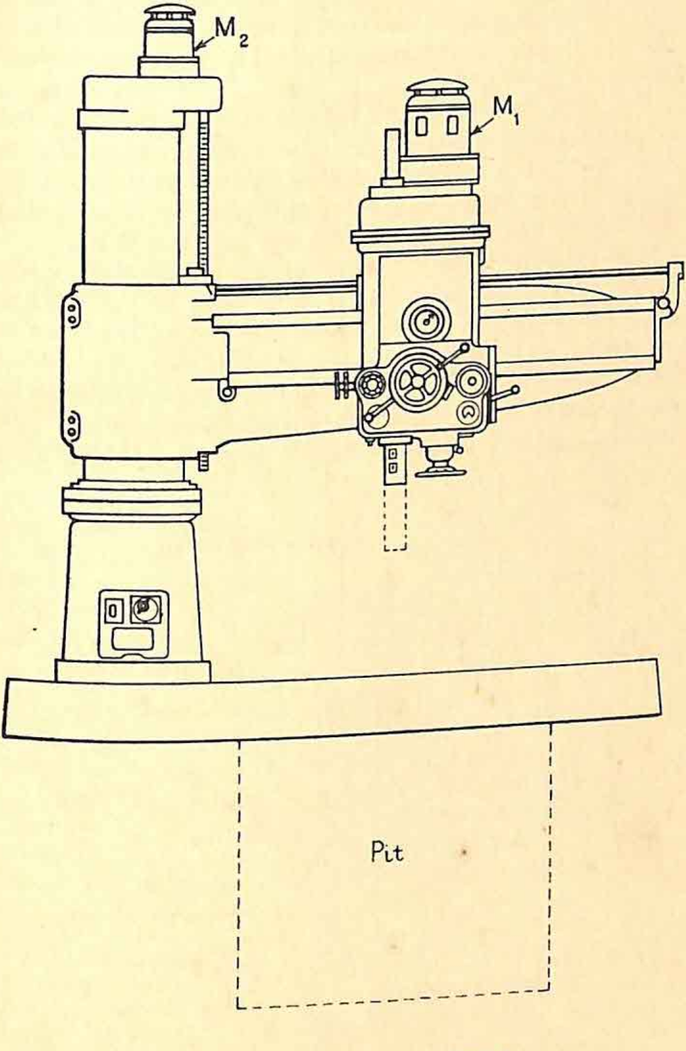


Fig. 156. RADIAL ARM DRILL.

A drilling machine of this type has the great advantage that the work can be clamped down at the start of a job and can remain undisturbed until all holes in one particular face have been drilled.

Fig. 157*b* shows an older type of machine of which there are still many in use. Here the work must be clamped down for each hole that is drilled. This particular machine is belt driven, the speed being obtained by coned pulleys and a back gear, the feeds from the gear box G.B.

The Sensitive Drilling machine is a light-weight version of the above machine which is freely used for drilling holes up to about ½ in. For such machines a power feed is neither necessary nor desirable. What is needed is a nicely balanced hand feed which gives the operator a sensitive feel when using small drills, which are always easily broken. The smallest of these machines can be fixed on a bench, whilst

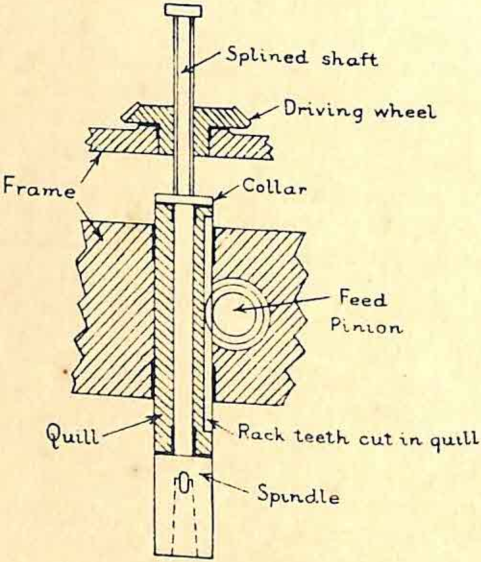


Fig. 157a

DRILLING MACHINE SPINDLE

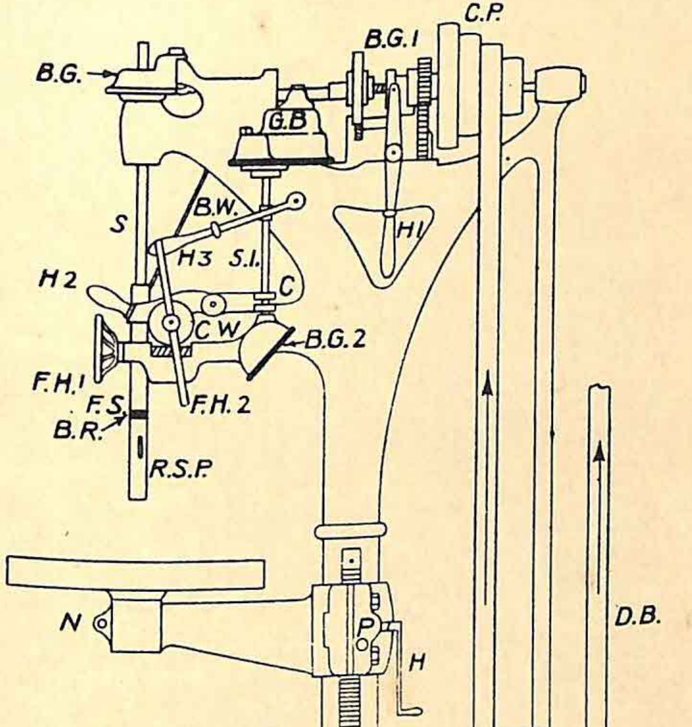
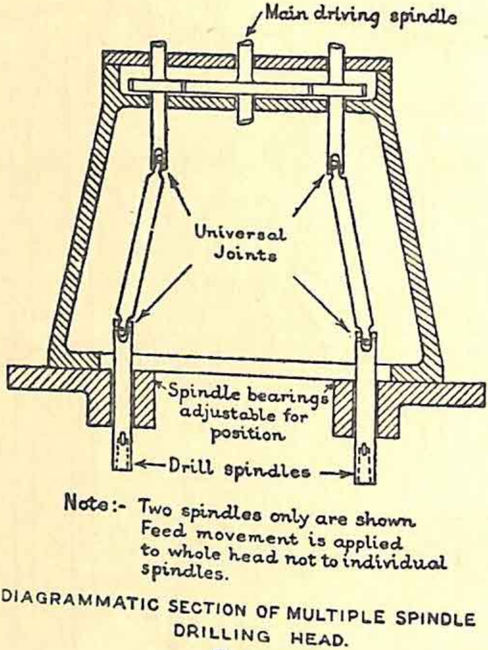


Fig. 157*b*.—Pillar drill

other designs which provide more extensive adjustment are fixed to the floor of the shop.



Note:- Two spindles only are shown
Feed movement is applied to whole head not to individual spindles.

DIAGRAMMATIC SECTION OF MULTIPLE SPINDLE DRILLING HEAD.
Fig. 157.c.

Multiple Spindle Machines

In specialized trades such as the motor industry it is common to build single-purpose drilling machines to suit a particular job. Such machines are fitted with many spindles and are capable of drilling all the holes in an engine block in one operation.

Some machines of this type could be regarded as general-purpose machines, and fig. 157*c* shows the arrangement of a multi-spindle head which can be adjusted to any particular lay-out of holes which is required.

CHAPTER XIV

Planing and Shaping Machines

These two machines are used to produce plane surfaces. In the shaping machine the work is held, whilst the tool moves over the surface of the work, and cuts on the forward stroke. The shaper is easier to operate and quicker in action than the planing machine, but the length of cut is limited by the length of stroke produced by the movement of the ram.

The shaping machine is worked by the slot-bar motion. When the wheel is revolved, the driving pin which is fixed to it moves in the slotted arm, thus causing a backward and forward movement of the arm. When the pin is at the lower end of the slot, nearest the fulcrum on which the bar swings to and fro, the arm will swing at a maximum speed. When the pin is at the higher end of the slot, the arm moves at a lower rate.

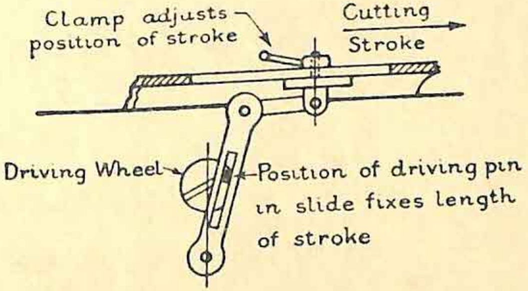

Clamp adjusts position of stroke
Cutting Stroke
Driving Wheel
Position of driving pin in slide fixes length of stroke

Fig. 158a.—Shaping machine mechanism

Stroke Adjustment

The length of stroke of the ram, or the length of cut that may be taken, is varied by moving the driving pin to or from the centre of the gear wheel. It is clear, therefore, that the nearer the driving pin is to the centre of the wheel, the shorter is the stroke. The position of the tool for any length of stroke can be changed by moving the handle (2), which is at the end of the movable arm. When the position of the tool is to be altered, the handle (2) is released, leaving the ram free to be moved to the required position; when this is adjusted to the correct length for cutting, the handle is tightened. Fig. 158 (3) indicates the section of the tool-box, which is allowed to swing forward by means of the pin A. This is of great advantage when the tool is coming back over the work, and if cuttings get under the tool.

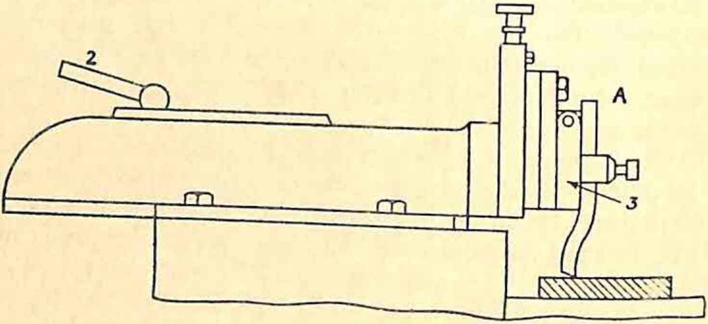


Fig. 158

The front view of the tool-box given in fig. 159 shows how the tool may be set for angular cutting, the tool-box head being graduated and swivelled through an angle of 180°, and fed down by the handle.

The feeding arrangement in shaping machines varies. In some, the tables on which the work is fixed are fed, whilst in others, the tool is fed along the work.

Shaping and Planing Tools

Although the cutting action of these tools is the same as that of lathe tools, there are certain practical differences which arise from the nature of the work.

The average job in a planer (or shaper) is well supported in the vertical direction by the table itself. This means that tools with a small plan angle, or round-nose tools, are used in preference to tools of the type shown in fig. 97.

Again, flat surfaces are more often wanted on iron castings than on steel, so again there is a preference for the round-nosed tool.

The need to pack a tool to correct height does not arise in these machines. Provided a tool is strong, its height is immaterial. Fig. 160 shows a type of tool that is sometimes used. Such a tool, when it bends, will deflect away from the work, which makes for smoothness of cutting.

Because of the nature of most of their work, planers and shapers are not provided with proper means of applying a cutting lubricant. For machining steel, make-shift arrangements are used.

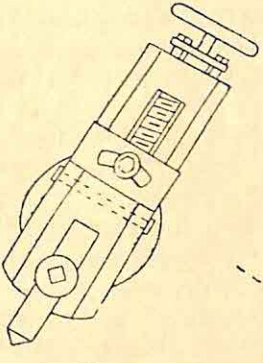


Fig. 159

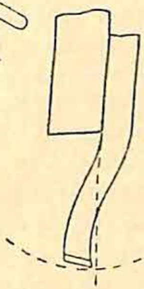


Fig. 160

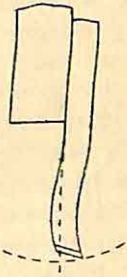


Fig. 161

The most suitable cutting speed for a given piece of work depends on the type of material to be machined and also on the size and rigidity of the machine. The following speeds will be found suitable for general classes of work on shaping machines.

Wrought iron,	20 to 50	ft.	per minute.
Mild steel,	20 to 65	,,	,,
Cast iron,	20 to 50	,,	,,
Brass,	50 to 90	,,	,,
Aluminium,	60 to 100	,,	,,

The feed given to the tool depends upon the toughness of the metal being machined, the amount of metal to be removed, the depth of cut, and the size of the work. The feed is very important, as to a great extent it decides the time required to complete the work. A roughing tool should be used to within about $\frac{1}{16}$ in. of the finished size, the remainder of the work being done with a finishing tool. It is not advisable to take heavy cuts on work of light section, as this will tend to spring the work out of shape. These remarks apply also to the planing machine.

Planing Machine

When the length of work requiring a machined flat surface is beyond the capacity of the shaping machine, a planing machine is used. In this machine the tool is fixed in a stationary tool-box, whilst the work, secured to the table, moves to and fro under the tool. Fig. 162 shows the front elevation and an end view of an ordinary type of planing machine.

The two uprights (3) are fastened to each side of the bed and support the cross-rail (4) upon their vertical faces. The cross-rail can be moved up or down by the handle (1), which operates mitre wheels and vertical screws within the uprights, and works in nuts attached to the rail. The saddle S can be moved across the rail by means of a screw, and the tool-box B is bolted to a circular facing on the saddle to enable the tool to be set for angular cutting.

The cutting is done while the table is travelling towards the tool-box, and this tool-box, as on the shaping machine, is pivoted to allow the tool to lift slightly on the return or non-cutting stroke. The table is driven by pulleys P at the side, one fast central one and two loose side ones. The pulleys carry open and crossed belts, which are shifted in turn on to the central fixed pulley, to drive in one direction or the other. The power is then transmitted to the inside of the bed by bevel gears, terminating in a large bevel gear which meshes with a rack attached to the underside of the table, and so drives the latter.

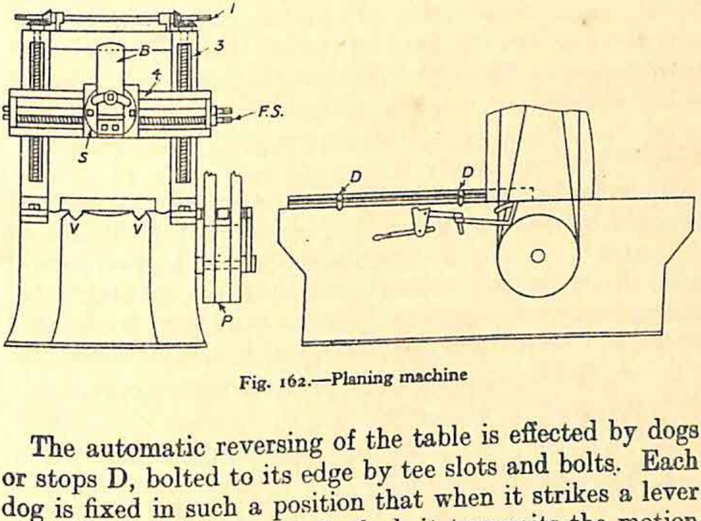


Fig. 162.—Planing machine

The automatic reversing of the table is effected by dogs or stops D, bolted to its edge by tee slots and bolts. Each dog is fixed in such a position that when it strikes a lever pivoted upon the side of the bed, it transmits the motion to other levers, terminating in belt-shifting forks over the pulleys. The table therefore travels and the tool cuts until a dog moves the striking arrangement, with the result that the fast pulley is suddenly vacated by one belt in order to make room for the other belt, which drives the pulley in the opposite direction. At the time when the belts are reversing, a feed is given to the tool-box by a vertical rack-bar placed behind the cross-rail and moved up and down by a small crank disc driven from the table gears. As the rack-bar moves, it partly rotates a gear wheel, which by a ratchet gives a partial rotation to the feed screw F.S. lying inside the cross-rail, or to the shaft above it, by which the down feed of the tool is obtained.

The vee form of sliding ways is generally used, because it obviates the necessity of using adjusting strips to keep the table in position and prevent it moving sideways. The weight of the table is sufficient to keep it down and steady against the cut. Owing to its weight, the oiling of the vees is an important matter, and to retain some of the oil in the vee channels, recesses are made in the bed, containing oil in which rollers are placed. As the bed moves over these rollers, it is kept lubricated. Some large planing machines have two tool-boxes, so that two cuts may be taken at once.

Chatter

An important defect which may occur when a shaping or planing machine is being used is what is known as "chatter". It may be found when machining cast iron or steel that a smooth surface is not obtained. In fact, small corrugations may appear, although sometimes in one part of the face only. This may be caused in several ways:

1. The work not being fixed firmly to the machine.
2. Slackness in some of the machine parts.
3. Variation in the grain or texture of the metal.
4. Vibrations of the tool.

The chattering usually comes from the vibrations of the tool, which may have become blunt and should be reground, or too much of the tool may be projecting from the tool-box. Only experience, however, will enable the worker to decide which of the above is the cause of the "chatter".

CHAPTER XV

Milling Machines

Milling machines have one thing in common with drilling and boring machines—the use of a revolving spindle. The action, however, is not the same, since in drilling or boring the feed motion is longitudinal, while in milling the feed motion takes place transversely to the spindle, so that the cutter held in the latter tools across the face of the work. The feed of a milling machine is continuous, not intermittent as in shaping and planing machines, because there is no to-and-fro cut with a return stroke. The time wasted in the return strokes is saved by milling, this being one of the many advantages of the process.

Milling, which may be described as a process of removing metals by means of revolving cutters, is employed extensively in machine shops, since it is the quickest and most accurate method of forming and finishing parts of machinery, tools, &c., to standardized dimensions and shapes. Practically any work that can be planed or shaped can, up to the capacity of the machine, be milled with advantage. Further, much more intricate work can be handled, owing to the greater range of movements available and the number of attachments specially designed to increase rapid and accurate production. When provided with a complete universal table movement, a milling machine is capable of performing a great variety of operations, e.g. plain milling, surfacing, edge-milling, grooving, recessing, keyway cutting, gear and cam cutting, thread milling, twist drill flute cutting, end milling, tee-slot cutting.

Intricate work involving many varied operations, if

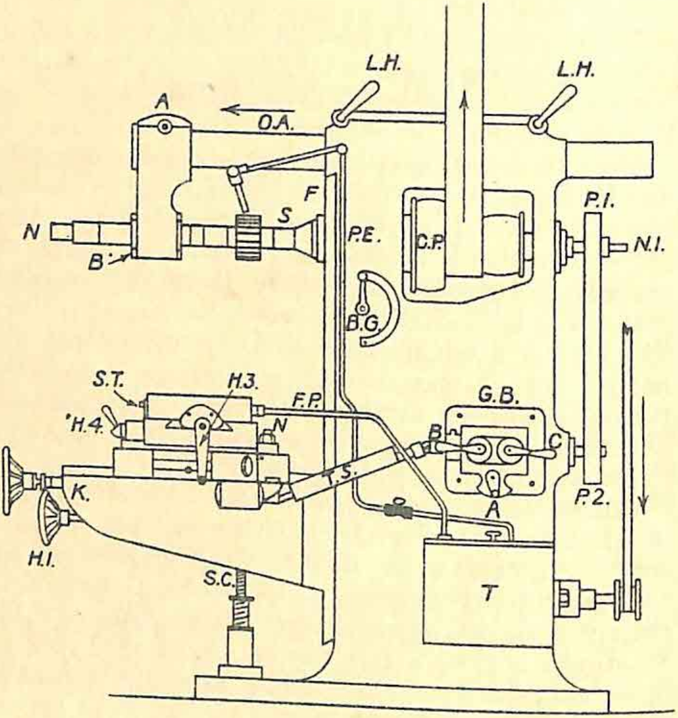


Fig. 163.—Universal milling machine

carried out on the shaper or planer, requires a large number of specially shaped tools, which have to be first forged and then ground to shape and hardened. The life of these compared with that of a milling cutter is very short, while the finish produced on the work by these tools cannot be compared with that of the milling cutter.

Modern milling machines are equipped with fine and extremely sensitive feed-adjustments which permit a specified amount of cut to be accurately set, in depths from the maximum of the cutter down to $\frac{1}{1000}$ in.

A useful type of universal milling machine is shown in fig. 163. This type is called the pillar and knee machine, the knee sliding upon ways on the vertical face of the pillar or column supporting the spindle. Increased usefulness is attained by making the work-table adjustable up and down, in addition to its longitudinal and cross movements. The table may be raised or lowered by the handle H1 (fig. 163) which is connected to the screw S.C. by a bevel gear. A cross-feed working of the table is obtained by the handle H2, and a longitudinal one by the handle H3. As the longitudinal feed of the table is considerable, time is saved and better work is produced by a power feed, driving from the driving spindle S and cone pulleys C.P., passing to P1 and P2, through the gear-box G.B., which drives a universal telescopic shaft T.S., connecting to a worm and worm-wheel working on the end of the screw. The telescopic shaft has ball joints, which allow it to bend and twist about in any direction, as is made necessary by the rising and falling of the table.

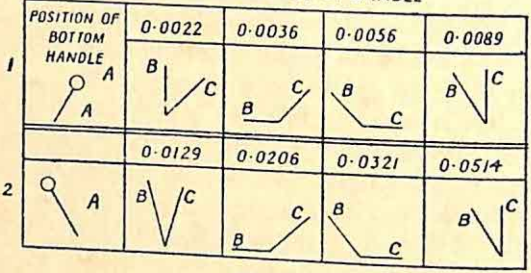
The table is mounted on a saddle with a circular base, which can be swivelled to turn the table into angular positions, in order to perform milling work out of the ordinary, such as making certain gears, worms, spiral forms, and twist drills, which require the cutters to be placed at an angle to the work. The table is made to run in either direction, because some work requires a change of cutting direction without the work being moved from the table.

Table Feed

The *feed* of the table is of great importance, and the necessary changes of feed are obtained by a nest of gears in the gear-box G.B.; any combinations required are obtained by sliding the gears so as to throw various sets into engagement. The table in fig. 164 shows how eight table feeds may be obtained by changing the position of the handles A, B, C. When handle A is placed in a vertical position, the gear-box is disconnected from the driving shaft. By the use of these geared feeds heavier cuts are possible.

The self-acting feed of the table is operated by the handle H4, and is thrown out of action by the stops or trips S.T.; these stops can be bolted to any desired position on the table edge.

TABLE SPEED IN INCHES PER REV. OF SPINDLE



	POSITION OF BOTTOM HANDLE				
1	A	0·0022	0·0036	0·0056	0·0089
2	A	0·0129	0·0206	0·0321	0·0514

Fig. 164

It will be noted that the spindle head resembles that of a lathe head, with cone pulleys C.P. and back gear B.G.

The spindle S is held in by a taper, which is tightened or released by means of a draw-in spindle, which lies in the hollow main spindle and is controlled by the nut N1.

The outer end of the spindle S is supported by a split bush B fitted within the overhanging arm A. Fitting loosely upon the spindle are a number of short sleeves or collars, while the outer end of the spindle has a locking nut N, the purpose of which is to clamp the sleeves tightly together when a cutter is placed between any two of them.

Small cutters may be held with sufficient security by the mere clamping effect of the sleeves on each side when the end nut is tightened, but large cutters require to be keyed to the spindle in order to prevent slipping under the heavier strains imposed on them.

When it is found necessary to change the cutter, the nut N on the spindle must first be loosened. The two locking handles L.H. which lock the overarm O.A. are then released to enable the cutter to be brought well clear of the spindle in the direction of the arrow. Before proceeding to remove the nut, sleeves, and cutter, it is always advisable to lock the overarm. When the required cutter has been placed in position on the spindle with the sleeves, the nut should only be made hand-tight; if an attempt is made to tighten the nut with a spanner while the spindle is not supported by the arm, the spindle may be bent. The overarm should now be replaced and locked, and the nut N then finally tightened.

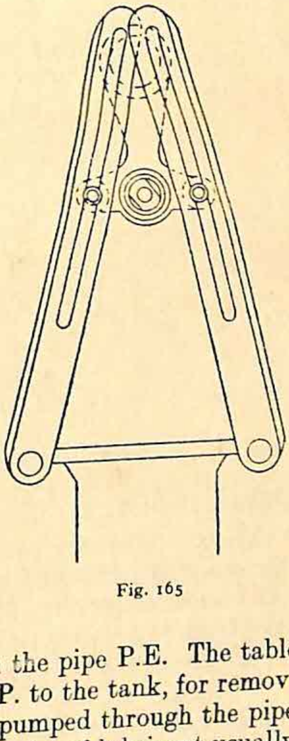


Fig. 165

The cutters are cooled by some form of cutting lubricant pumped from the tank T through the pipe P.E. The table is provided with a flexible pipe F.P. to the tank, for removing the lubricant which has been pumped through the pipe P.E. The latter is fixed so that the jet of lubricant usually plays on the cutter at the point where it is actually cutting. This not only cools the cutter, but washes away the hot chips. The waste lubricant passes through strainers before again reaching the pump. When heavy work is being carried out the overarm is joined rigidly to the knee K by means of cross-stays as shown in fig. 165.

Vertical End-milling Attachment

This attachment is employed for all types of end-milling. The overarm and spindle are dismantled and the attachment shown in fig. 166 is bolted to the face of the machine F and driven by means of an arbor in the main spindle.

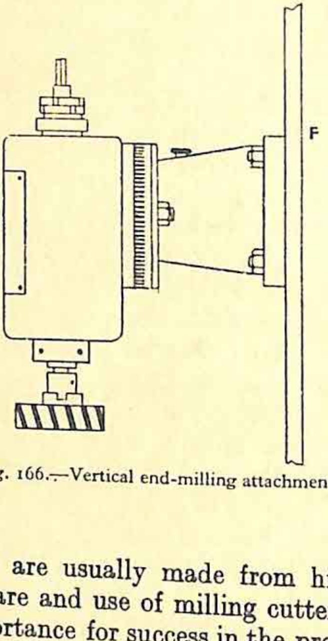


Fig. 166.—Vertical end-milling attachment

Milling Cutters

These cutters are usually made from high-speed steel. The selection, care and use of milling cutters are points of the utmost importance for success in the process of milling, and failure to obtain satisfactory results may often be due to the use of the wrong cutter.

As a rule, milling cutters are made with the front faces of the teeth radial, thus giving no angle of rake. Exceptions to this rule are found chiefly in large inserted-tooth cutters, in which there is a certain amount of rake which tends to promote smoother cutting with less power consumption.

The clearance or relief of a milling cutter is the amount of material removed from the top of the teeth away from the cutting edge in order to permit the teeth to clear the work and not scrape over it after the cutting edge has done its work. Correct clearance limits should be rigidly adhered to in the grinding of cutters. They depend upon the diameter, and must be greater for small cutters than for large ones. The recognized standard of tooth clearance for plain milling cutters should be 4° for cutters over 6 in. in diameter, and 6° for those under 3 in. in diameter. The top of a cutter when new should be from ·02 in. to ·04 in. wide, the tooth angle being approximately 50°. These details are shown in fig. 167.

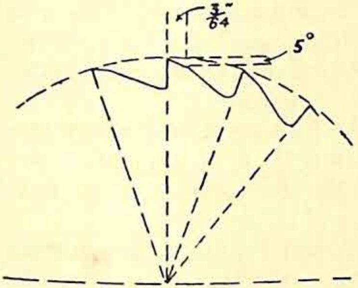


Fig. 167

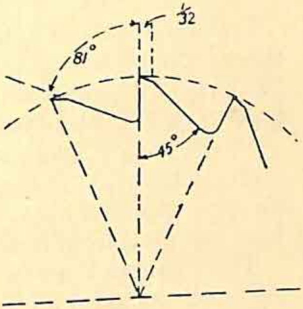


Fig. 168

The number of teeth for a cutter should be the smallest that will allow at least one tooth to be at work all the time. As, however, milling cutters are used for general-purpose work, the number of teeth tends to become standardized for a particular type of cutter. Thus the following may be taken as examples of current practice:

3″ dia. × 4″	Plain Mill	12 teeth
4″ dia. × ¾″	S. and F. Cutter	20 teeth
1″ dia.	End Mill	8 teeth
6″ dia.	Slitting Saw	42 teeth

These may be regarded as normal practice for production work, but useful cutters can be made with two teeth, or even one. Such cutters are slow in use but can be made very cheaply for doing special jobs.

Narrow cutters can be used with straight teeth, but for wide cutters the teeth must be helical, or chattering results.

The amount of twist given is largely a matter of choice, and convenience in grinding. A helix angle of up to 45° is good modern practice, and has the effect of allowing the cutter to run smoothly with fewer teeth than would otherwise be needed.

Types of Cutters

The Plain (or Cylindrical) milling cutter (fig. 169) cuts only on the circumference. Its main use is for flat surfaces. The ends of the cutter are slightly dished to allow the cutter to clear itself at shoulders.

The Slotting Cutter and the Slitting Saw are extreme forms of the plain milling cutter. Both these cutters have the property that they will hold the width of a cut well, but may wander off direction.

The Side and Face Cutter (S. and F.) has proper cutting edges on the sides of the teeth. It is the proper tool for doing such work as shown in fig. 172. In the figure two cutters are shown working together, but the job may alternatively be done with one cutter in two runs.

The End Mill and the Face Mill are one-sided forms of the side and face cutter. (Figs. 170 and 173.)

Special cutters commonly used are shown in figs 174–5. It is to be noted that any form cutter is ground in the flute so as to leave the form intact.

Any milling cutter which is not symmetrical is either right- or left-handed, and this must be borne in mind when ordering a cutter for a particular milling machine. Although some machines are reversible there is usually a "best way" for doing any particular job.

Direction of Feed for Cutters

It is of the greatest importance that the work shall be arranged on the milling machine table in such a way that it moves forward to the cutter in one direction only, the direction being opposite to that along which the cutter runs. The right and wrong methods of doing this are shown in fig. 177, A being the correct method and B being the

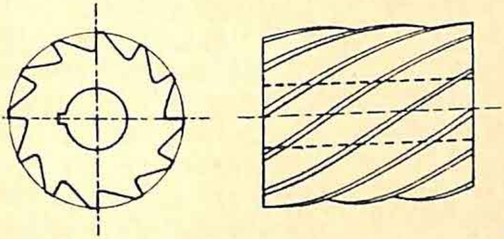


Fig. 169.

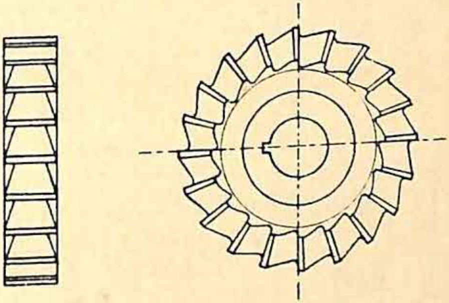


Fig. 170.

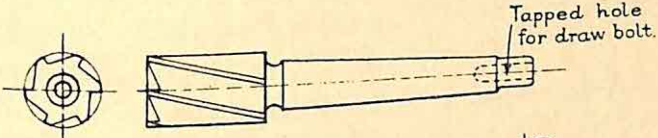


Fig. 171.

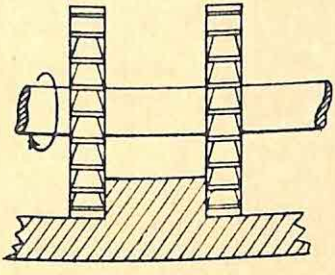


Fig. 172.

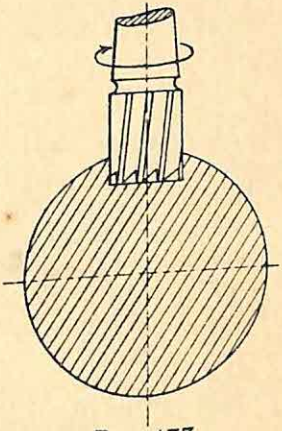


Fig. 173.

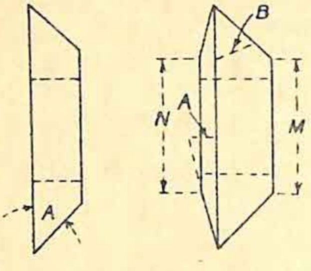


Fig. 174.—Bevel cutters

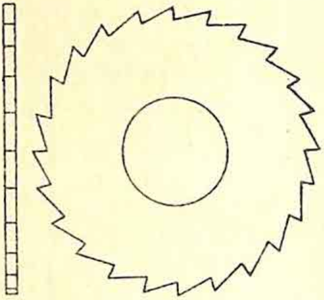


Fig. 176.—Slitting saw

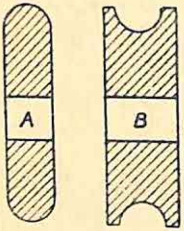


Fig. 175.—Radius cutters

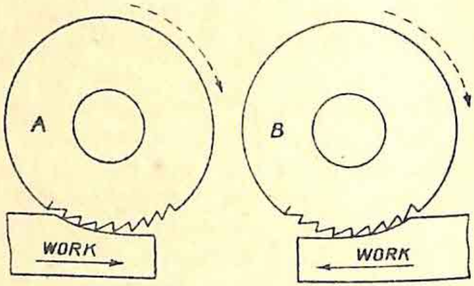


Fig. 177

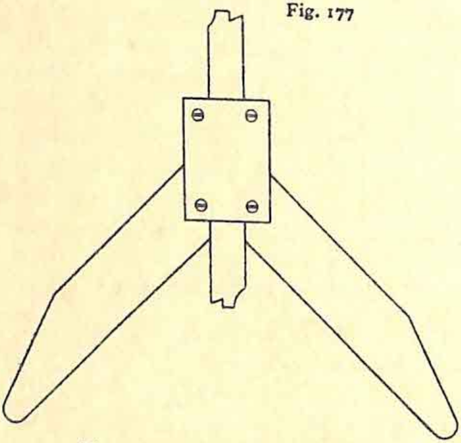


Fig. 178.—Cutter clearance gauge

incorrect. It will be seen from B that the cutter is running in the direction of the arrow and the work is also travelling in the same direction. The cutter would exert a dragging action on the work, and if there were any lost motion in the table screw and nut, the cutting action would be choppy and jerky, and broken cutter teeth would probably result.

The correct movements are shown in A. Here the cutter teeth work from the bottom upwards, lifting the hard scale, after the cutter has entered the softer part of the work. A cutter used as at A will probably last much longer than one used as at B.

True Running of Cutters

A cutter on its spindle should run as true as possible. To achieve this the spindle should be treated carefully. Once bent it can never be made quite straight again. The cutter should always be placed as near to a steady as the job will allow. In spite of all precautions no milling cutter runs dead true, and all will leave a slight ripple on the finished work. This is unavoidable.

Speed of Milling Cutters.

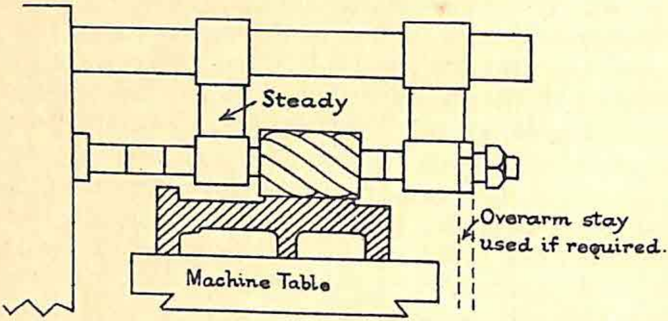
This should be rather slower than the speed used for turning the same material on a lathe. A good "rule-of-thumb" method is that a cutter should run at a speed at which it is just possible to see the teeth.

Grinding Milling Cutters

A dull cutter wears very rapidly and produces poor work. As soon as there is any appearance of dullness in a cutter, pass it once or twice across a grinding wheel, which should be mounted upon a suitably designed machine (cutter grinder). This in the long run will save time in sharpening, prolong the life of the cutter, and enable it to do its best and most rapid work.

Lubricant

With all cutters a lubricant should be used freely when milling wrought iron or steel. Water soluble cutting oil is



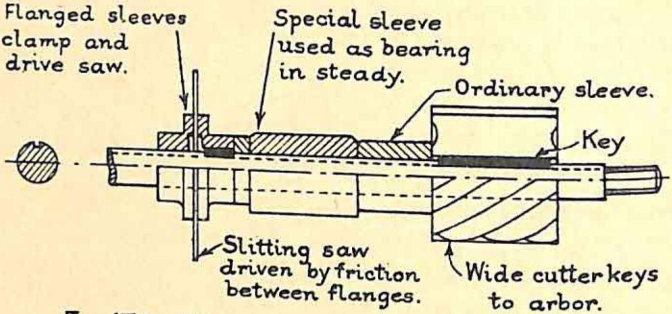

Flanged sleeves clamp and drive saw.
Special sleeve used as bearing in steady.
Ordinary sleeve.
Key
Slitting saw driven by friction between flanges.
Wide cutter keys to arbor.

Fig. 179. MOUNTING OF CUTTERS ON ARBOR.

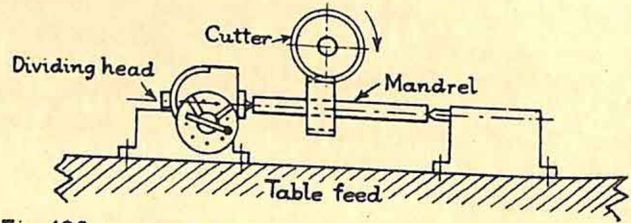


Fig. 180. DIVIDING HEAD SET UP FOR CUTTING GEAR TEETH.

suitable in most cases, but for special work a pure cutting oil may be an advantage.

Dividing Head

This useful attachment is used for milling the teeth of gear wheels or any other jobs where successive cuts must be spaced regularly round a circle. The head itself is similar to a lathe head, and is bolted to the table. The spindle can be rotated by a worm, and the exact angle put on by means of a disc with accurate holes drilled in it. Several discs are usually supplied, so that any practical number of teeth can be cut.

Cutter Clearance Gauge

This handy gauge (fig. 178) is designed to determine the correct angle of clearance in grinding milling cutters, and is very simple to use. The inside surfaces of the vee are brought in contact with the cutter, and the gauge blade is dropped upon the tooth being tested. The cutter is revolved sufficiently to bring the face of the tooth in contact with the gauge blade. The angle of clearance in the tooth should correspond with the angle of the gauge. The gauge may be used for right- and left-hand cutters, and for end mills of all types. The vee-shaped body locates the cutter and holds the gauge blade in correct relation to the centre line of the cutter. The two gauge blades are stamped at each end with the diameter of the cutters for which they are intended to be used. This clearance gauge will measure all types of cutters, from ½ in. up to 8 in. in diameter, and of any width.

CHAPTER XVI

Grinding and Grinding Wheels

The improvement in the manufacture of grinding wheels and the abrasive materials from which they are made, is largely responsible for the development in grinding practice that has taken place during recent years. This improvement is due to the great demand for hardened steel components. No machine shop is complete without a suitable proportion of grinding machines.

Precision grinding, as it is termed to-day, is an industry of very recent growth. Formerly the accuracy of the finished machined product depended upon the skill of the operator and the accuracy of the machine on which the work was done. The part was finished by a cutting tool, with perhaps a final application of emery cloth or a smooth file, and great difficulty was experienced in removing fine layers, of say two or three thousandths of an inch, by means of the cutting tool.

Before the advent of precision grinding machines, hardened parts were necessarily finished before the heat-treatment, so that no matter what care was expended on machining, the accuracy of the part was bound to be affected by the hardening process, and the warping and shrinkage that occurred could not afterwards be corrected. Nowadays, however, care in the hardening shop to avoid these defects is not so important, for the part is roughly finished on the machine, some thousandths of an inch oversize, then hardened, and finally ground true to size on the grinding machine.

It must not be thought from this that grinding is only applied to hardened pieces of work; the fact that very fine cuts can be taken with the grinding wheel is often taken advantage of in bringing soft pieces to size, and the very fine finish given reduces the amount of subsequent fitting. Still, the grinding machine is not likely to displace other types of machine-tools as a metal-removing agency pure and simple. For finishing operations, the grinder is superior to any other class of machine, with respect to finish, accuracy, and time taken, not only on repetition work, but, in many cases, on single pieces, and the great ease with which a grinder may be set up ready makes it an ideal machine for all classes of work.

The grinding wheel itself may rightly be considered as a multiple-toothed cutting tool. The myriads of grains which constitute a grinding wheel are each single cutting tools. These cutting points should be so held together that, as soon as they become dulled, they fly off and expose fresh cutting edges. This action is described as *abrasion.*

Construction of Grinding Machines

The principles governing the construction of grinding machines differ from those of any other machine tool. Most machining operations are of a primary character, the ultimate finish being produced by other means, e.g. by the file or scraper, whereas the grinding machine is a finishing machine, and the work produced needs no further correction. It naturally follows that all the sliding surfaces of the machine must be perfectly true planes, otherwise accuracy in the product is impossible, and the greatest care has to be taken in construction to see that this end is attained. The sliding surfaces are always very long, and with proper lubrication the wear tends to be distributed evenly over a large surface, so that the alignment is preserved.

Rigidity

Rigidity in any machine tool is a necessity, but in none more so than in the grinding machine. The wheel head in particular should be held most rigidly, for any weakness in this portion tends to cause vibrations, and renders the machine unable to meet the demands of the work, both in quality and quantity. This is one reason why the majority of makers prefer to have the grinding wheel carried on a stationary part of the bed, the movable bed and work moving past the wheel. Heavy grinding wheels can thus be carried without vibration, because the wheel head and its slide rest upon a solid base. As this part of the machine also carries the cross-feed mechanism, there is less liability to distortion and intermittent motion of the wheel head, and a sensitive control to the feed at all times is thereby ensured.

It should be pointed out that the work produced on a grinding machine is only a reproduction of the grinding wheel itself, and that for cylindrical work the grinding wheel must be a perfect cylinder, or good work cannot be produced. Unless the wheel head has the rigidity necessary to overcome possible adverse conditions in the wheel itself, it is impossible to make the wheel perfectly cylindrical, and faulty work is the result. It is for this reason that a grinding machine cannot very well be improvised. Many attempts have been made to convert a lathe into a grinding machine by means of attachments, but with only moderate success, owing to the lack of the necessary rigidity.

The spindle of the grinding machine is of the highest class of workmanship. The adjustments should not be tampered with, and any adjustment required to take up the wear should be undertaken by someone with a knowledge of the construction of the bearings and conditions under which the spindle should run.

For good running condition, the bearings should be at a temperature of 100 to 120° F. To maintain the constant temperature, a grinding wheel spindle is usually left running all day long, even when all other movements are stopped. The spindle should be well lubricated and carry a constant film of oil, so that there is no metal to metal contact between the spindle and the bearings.

The design of spindle bearings varies widely with different makers. For cylindrical grinders some form of plain bearing is usual, with elaborate means of adjustment of clearance and a self-contained lubricating system. Fig. 181 shows such a bearing.

The bearing bush is split at the top and can be tightened by drawing it farther into its tapered housing by nut C. Wedges W, W are used to expand the gap and so force the bush firmly into the housing. This is necessary to maintain the circular shape of the bush.

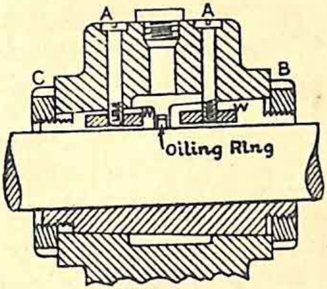


Fig. 181

Alternatively for internal and universal grinders very high-quality ball or roller bearings are used.

The Precision Cylindrical Grinding Machine

The principle of the precision grinding machine does not differ greatly from that of the lathe. The machine possesses a headstock and tailstock, and movement for the traverse of either the grinding wheel (when the work is stationary) or the work (when the wheel merely revolves and does not traverse). So far as the grinding wheel is concerned, there is no difference between these two types, and each type has advantages which render it convenient for certain classes of work.

Surface Grinding Machine

This term is usually applied to machines used for grinding plane surfaces. There are many types, but they are all constructed on one of two general principles. In one the grinding wheel revolves upon a vertical spindle, the axis being at right angles to the surface that is being ground. A cup or cylinder wheel is used, and the actual grinding is done by the rim.

In the other type the axis of the wheel is parallel to the work, the grinding being done with the face of the wheel.

The type chosen depends on the class of work. The two types give different surfaces; with the cup or cylinder vertical-spindle type, the grinding lines of the surface are a combination of arcs of circles, whereas when grinding with the face of a straight wheel, the grinding lines are parallel.

Disc Grinders

These are surface-grinding machines in which the table revolves. Here also there are two types, one using the vertical spindle with the cylinder or cup wheel, and the other a straight grinding wheel. In some cases these machines are specially constructed for grinding discs, but they are chiefly used for shapes of various kinds other than the disc. They are generally used to grind a number of small pieces of work which are mounted on the revolving table.

Tool and Cutter Grinder

These machines are generally of the universal type, and often have attachments by which the various operations necessary in the grinding of milling cutters, reamers, saws, taps, end mills, twist drills, and lathe centres can be carried out.

Internal and plain surface grinding can also be done. The work table may be swung round to suit the machine to the work, and a graduated scale is provided by means of which the table may be accurately set. A cross feed is operated by means of a hand-wheel, and tapers may be ground by an adjustment of the swivel table.

Portable Grinders

A very common type of portable grinder, which may be used in a lathe tool-post or bolted to a milling machine table, is shown in fig. 182. It is electrically driven by a small motor; the grinding wheel A, attached to the armature shaft, has a spindle speed of 10,000 revolutions per minute for external grinding. By means of a belt driving from A, the small wheel W has a spindle speed of 30,000 revolutions per minute for internal grinding.

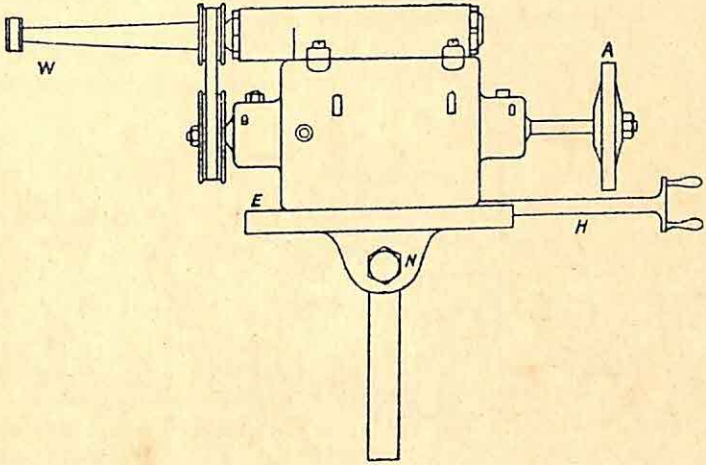


Fig. 182.—Portable grinder

This grinder may also be used for taper work, for when the nut N is released, it can be swung round to any angle. It can be secured to the lathe tool-post and moved along by means of the lead-screw in the same manner as an ordinary cutting tool, or for short work the handle H is used, giving a movement of about 3 in. For convenience this handle can be removed and used at the other end E.

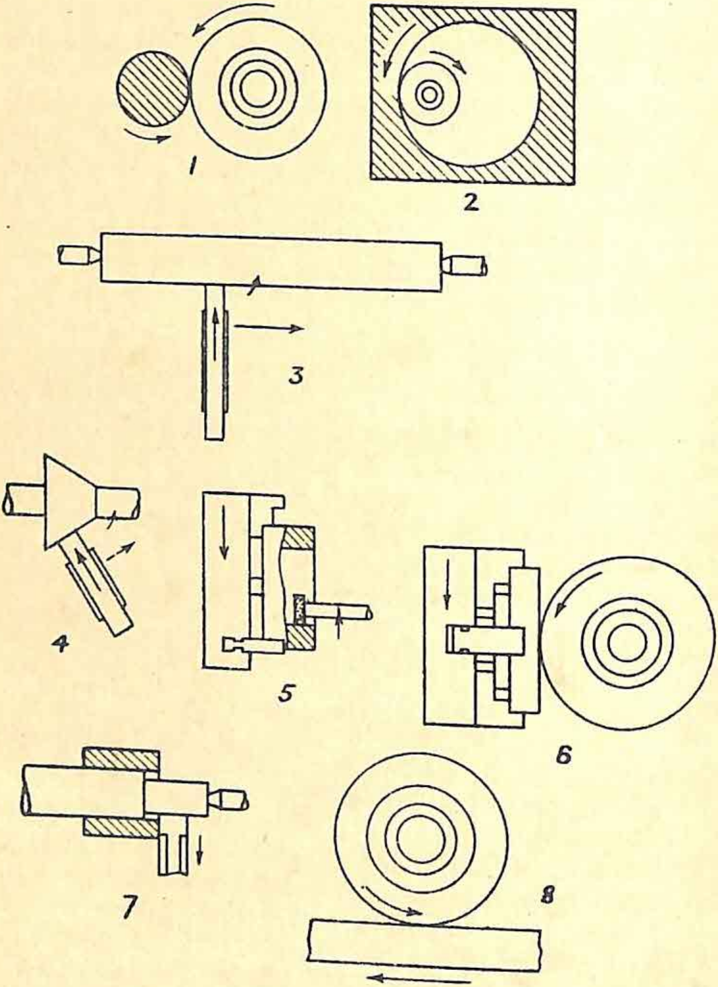


Fig. 183.—Some grinding operations

The Centreless Grinder

This machine is interesting because it has no counterpart milling machine. Fig. 184 shows its method of action.

The two wheels are powered by separate motors. The main wheel runs at an ordinary grinding speed. The control wheel runs at a speed corresponding to the required speed of the work. The work *rolls* on the control wheel, whereas it is ground by the main wheel.

The main wheel is mounted on a slide which allows the gap to be adjusted to the required diameter of the work. **The rest can be made of cast iron, or for longer runs of hardened steel or other wear-resisting metal.** The method of feeding is by inclining the axis of the control wheel, which has the effect of making the bar move lengthwise at a rate proportional to the angle of the control wheel.

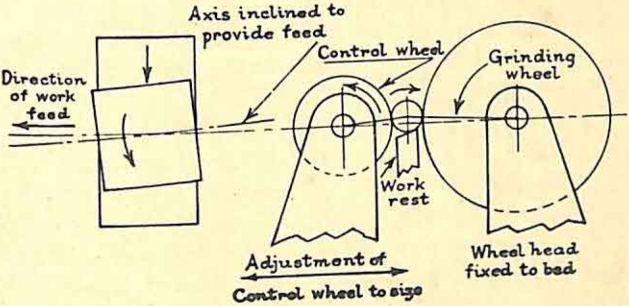


Fig. 184

This machine is excellent for mass production of round work, particularly long slender bars.

Grinding Operations

Fig. 183 shows several common grinding operations, and the direction of the grinding wheels and work:

(1) Grinding a circular spindle; (2) grinding a bore; (3) grinding between centres; (4) grinding at an angle; (5) chuck work; (6) face grinding in a chuck; (7) facing a bush; (8) surface grinding.

Tool Grinding

The best type of grinder for single-point lathe tools, chisels, etc., is the type where the grinding is done on the side of the wheel. The older type where the periphery is used gives satisfactory results, but it is much harder to get tool angles correct as the grinding surface is curved.

Tools can be ground wet or dry. If ground wet it is important that there should be plenty of water, or cracked tools will result.

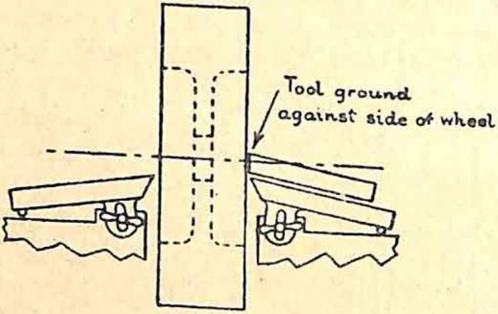


Fig. 185.

Grinding Wheels

There are several factors which have an important bearing upon the ultimate characteristics developed by grinding wheels. These are determined principally by the abrasive material used, the method employed in the manufacture of the wheels, and the nature and proportions of the bond. There are two types of abrasives which are extensively used, the silicon carbide abrasive (carborundum) and the aluminous abrasive (aloxite).

Carborundum differs materially from aloxite. The grains of carborundum are considerably harder than those of aloxite, and are also more brittle. The grains of aloxite, though not so hard, are tougher and therefore do not fracture so easily. Because of the difference between these two abrasives, carborundum is recommended for the grinding of all materials of low tensile strength, and aloxite for work on materials of high tensile strength. For grinding materials of low tensile strength, such as cast iron, brass, bronze, aluminium, copper, and for such non-metallic materials as rubber, pearl, marble and stone, carborundum is recommended. Aloxite is used in grinding steels and their alloys and in carrying out the majority of tool-room operations.

Since modern grinding has become an industrial art, involving definite scientific principles, the selection of the proper wheel for a given piece of work can no longer be left to guesswork. There are several very definite factors affecting the proper selection of a wheel, and these factors must be fully understood in order to ensure the correct grit or grain of the wheel. They include: (1) Material to be ground; (2) Amount of material to be removed and the finish required; (3) Method of grinding (hand or automatic); (4) Type, size, and condition of machine used; (5) Speed of the wheel.

The grain size or grit means the size of the abrasive grains or particles used in the making of wheels. The grains are graded by sifting through screens having so many holes or meshes to the linear inch. The grains are indicated by standard numbers corresponding to the number of meshes in the screen through which they pass. For instance, a twenty grit is a grain that will pass through a screen having approximately twenty meshes to the linear inch.

In the case of the very fine sizes known as powders, the grading is done by water flotation. The powders known as F, FF, and FFF are produced by commercial grading, while the powders ranging from 280 to 400 are graded to the closest possible degree of accuracy under microscopic control (see table, p. 138).

The degree of hardness which a grinding wheel possesses is termed its grade, and indicates the strength of the bond or the action of the bond in holding the grains in the wheel, in other words, the resistance which the bond offers to these forces which tend to break down the wheel structure. The different gradings are produced by the variation of

STANDARD GRAIN SIZES FOR CARBORUNDUM AND ALOXITE

Very Coarse	Coarse	Medium	Fine	Very Fine	Powders: Commercial Grading	Powders: Microscopic Grading
6	12	30	70	150	F	280
8	14	36	80	180	FF	320
10	16	40	90	220	FFF	400
	20	50	100	240		
	24	60	120			

the amount and character of the bonding material used.

It should be remembered that the term hardness or grade of a wheel does not refer to the hardness of the abrasive material used in its construction. A soft graded wheel may be made of the hardest of abrasives.

There are several types of bonding materials used in the manufacture of carborundum and aloxite grinding wheels, and according to the bonding used, these wheels are known as vitrified process wheels, silicate bonded wheels, shellac bonded wheels, rubber bonded wheels or "Redmanol" bonded wheels.

Vitrified Process Wheels

The majority of grinding wheels used in industry are made by the vitrified process, in which the abrasive grains are bonded with certain ceramic clays. Wheels made by the vitrified process can be made in a much wider range of grades, and can be used on more varied classes of grinding work, than any other type of wheel; in fact, they can be used in practically all classes of grinding.

Silicate Bonded Wheels

Silicate wheels are those in which the bonding agent is silicate of soda. With this bonding agent, wheels which have what may be termed a mild grinding action are produced. They cut with less harshness than vitrified wheels, and are principally used in the grinding of fine edge tools, knives of various kinds, and cutlery generally. Other advantages offered by these wheels are the possibility of making wheels of larger diameter, and the fact that silicate bonded wheels can be made in less time than vitrified wheels.

Rubber Bonded Wheels

For many grinding operations carborundum and aloxite wheels are bonded with rubber. With this bond it is possible to make extremely thin or wide-faced wheels. The thin wheels are generally used for cutting off work, and the wide-faced wheels for the grinding of steel and malleable castings. Rubber bonded wheels are also used where a fine finish is required, such as is required on ball-races, &c. For efficiency those wheels must run at higher speeds than vitrified wheels, and owing to the nature of the bond, this can be safely done, even in the case of small wheels.

Redmanol Bonded Wheels

Redmanol is a synthetic resin or bakelite which after long experimental work has been found to be an ideal bonding agent in the manufacture of carborundum and aloxite wheels that are used for cutting off small stocks of any kind of steel, alloy steel, or other materials. These wheels can be made extremely thin and run at high speeds with safety. Thick or wide-faced wheels are also being used with much success in the finishing of cams, and in other work requiring a high finish.

Diamond Wheels

Diamond dust, because of its great hardness, is an excellent abrasive.

It is usually bonded in bakelite or in metal. Such wheels are unrivalled for finish grinding tungsten-carbide tools, but because of their cost must be used with great care.

Speed and Hardness of Grinding Wheels

The surface speed of a grinding wheel is not quite so critical as it is for a lathe tool, but it is one of several factors which must be balanced with each other if good work is to be obtained. The ideal in grinding is for the wheel to wear away just fast enough to remain sharp (i.e. to avoid glazing). To wear faster is wasteful; to wear slower leads to glazing.

When a wheel wears fast we say it is "acting soft", and conversely a glazing wheel is "acting hard".

Wheel Acts Hard with:	*Wheel Acts Soft with:*
High wheel speed.	Low wheel speed.
Low work speed.	High work speed.
Large diameter, flat or internal work.	Small diameter work.
Large contact surface.	Small contact surface.

The correct selection of these variables to suit the job is part of the grinder's art. Usually a speed of about 5000 ft. per min. is used and the wheel grade chosen to suit. When a wheel has proved satisfactory for a certain job it is important that replacement orders give the full specification that is marked on the label.

Quite apart from these considerations, a wheel should never be run beyond its maximum safe speed or it will burst by centrifugal force. The rule for working out the surface speed of a grinding wheel is exactly the same as for the surface speed on a lathe.

Truing of Grinding Wheels

As all grinding wheels must wear it is necessary to "true" them up to restore their shape. This is done by an industrial diamond mounted on a holder which is fixed to one of the slides of the machine. The movement of the machine is then used to traverse the diamond across the wheel, which is in effect "turning" it in position. By this means the wheel can be made into a true cylinder, free from wobble *provided the spindle itself is steady.*

Shapes of Grinding Wheels

Grinding wheels are made in a very large number of shapes to suit various classes of work. In addition to the disc wheels for plain grinding, there are a variety of other shapes, a few of which are shown in fig. 186.

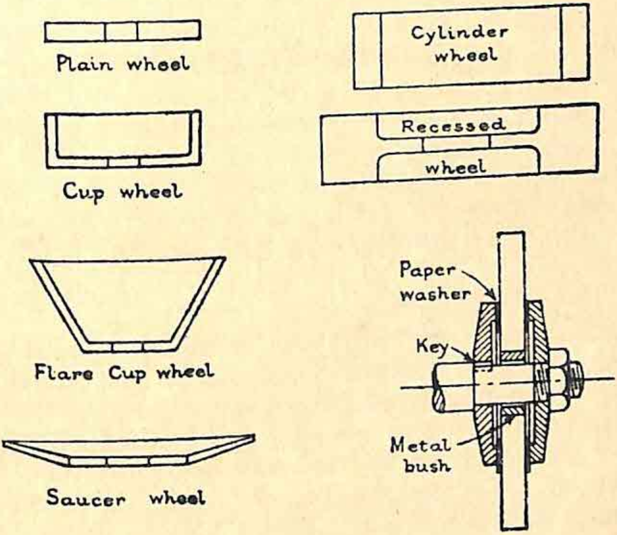


Fig. 186

Wheel Mounting

Grinding wheels are mounted between flanges, as shown in fig. 186. The points to note are that the flanges should bear near their rims, not in the centre, and that paper or rubber washers should be used to get a firm grip on the wheel without cracking it. The hole in the wheel should be a free fit on the spindle. As there are no universally accepted standards for the diameters of grinder spindles, it is often convenient to order wheels with a large hole and use bushes as shown. This enables one set of wheels to be common to several machines.

CHAPTER XVII

Belts and Transmission

It has been mentioned previously that a great many machines are driven by means of a small electric motor giving a direct drive to each machine. In a large number of cases, however, it is still necessary to use a belt to transmit power from the main shaft to the machine.

Belting

Driving belts are usually made of leather, rawhide, or chrome leather, but woven material is now largely used also. The following advantages are claimed for the latter belts; (1) They give great strength with flexibility; (2) they are unaffected by variations of temperature, water, or steam; (3) owing to the superior strength of the material, a much thinner belt can be used.

Laminated Leather Belt

This belt consists of a number of strips of leather through which holes have been punched at regular intervals. Through these holes thread is drawn so that the strips are stitched together and form a belt of any required width. The splicing is done in the same way, with the result that the belt is of uniform thickness, and can be increased to any length, free from splicings.

Use of a Belt

To obtain an efficient drive by using a belt, the belt must have the following properties: (1) Flexibility; (2) small stretch; (3) uniform thickness throughout; (4) homogeneity.

If a belt is not flexible it will not give an efficient drive, owing to bad contact with the surface of the pulley, and consequent slipping. When a belt is not homogeneous it wears very badly, and after very little use the belt slips and often tears. Cheap belts have these faults, whereas the best belts manufactured have all the qualities necessary to give an efficient drive without loss of speed through slipping.

After a belt has been in use for some time, it will become slack and will not grip the surface of the pulleys firmly enough to overcome the resistance. When this happens the driven pulley will not travel at the same speed as the belt, owing to this slipping on the pulley. When the slackness is slight, a belt dressing may be applied to the surface of the belt to prevent slipping. A number of good belt dressings for this purpose are obtainable. If the slackness increases it will be necessary to shorten the belt.

When possible, it is preferable to run with a slack belt which has had a dressing applied, as a tight belt tends to overheat the bearings.

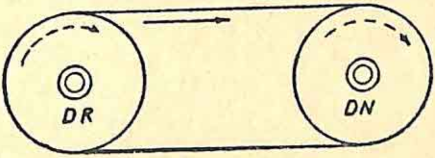


Fig. 187.—Open belt

Open Belt

Fig. 187 shows an open belt, which is used when the driven pulley DN is required to rotate in the same direction as the driver DR.

Crossed Belt

Fig. 188 shows a crossed belt, by which the driven pulley DN is made to rotate in the direction opposite to that of the driver DR. The faces of the belt will rub where they cross one another, but the wear will be only slight.

In each case the most efficient drive is obtained when the driving and driven pulleys have equal diameters.

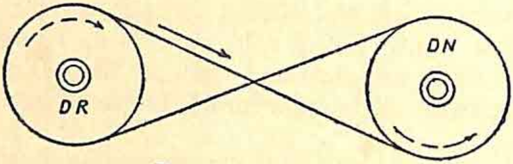


Fig. 188.—Crossed belt

Driving Arrangements

In belt power transmission, provision is made for stopping and starting the machine while the main shaft is revolving. The width of the belt is less than that of the fixed or loose pulley, but the width of the driving pulley

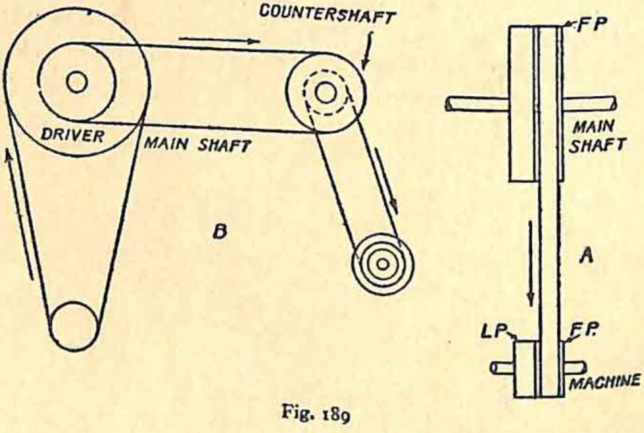


Fig. 189

is equal to the combined width of the fixed pulley and the loose pulley. Fig. 189B shows the general arrangement. The main shaft is driven by the motor, the belt from which is on the loose pulley; this enables the motor to be started without revolving the main shaft. Then by means of a striking gear the belt is moved on to the fixed pulley, thus revolving the main shaft.

The machines may be driven from the main shaft by two methods:

1. A direct drive from the main shaft to the machine, which has a fixed pulley on the driving spindle, as shown at A in fig. 189.

2. From the main shaft, to a countershaft, thence to the machine. A countershaft is an intermediate shaft with belt pulleys, by which speed changes are effected and machines are started and stopped. This method is shown at B in fig. 189. When the main shaft is revolving, the belt on the driving pulley will be revolving the loose pulley on the countershaft in B and on the machine spindle in A. When the machine is to be started, the belt is pressed sideways on to the fixed pulley by means of forks.

Crowning

The face of pulleys should be slightly rounded; this is termed crowning (fig. 190). The belt will always tend to rise to the highest point of the face.

The crowning of rapidly revolving pulleys should be very slight, as the sides of a fast running belt tend to lift, and if the crowning is considerable the area of contact is reduced, causing the belt to slip.

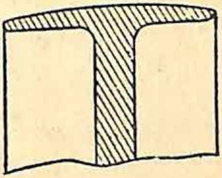


Fig. 190.—Crowning

The crowning of pulleys should be $\frac{1}{2}$ in. per foot of width, and the width of the pulley should be one-fourth greater than the width of the belt.

Speed of Machines

The speed of the machines is governed by: (1) the speed of the main shaft; (2) the diameter of the pulleys.

If the diameter of the driving pulley is equal to that of the driven pulley, they will make the same number of revolutions when connected by a belt. To increase or decrease the speed of the driven pulley, it is necessary to decrease or increase its diameter.

A simple example is given in fig. 191. The speed of the main shaft A is 300 revs. per minute. The diameter of the driving pulley B on the main shaft is 12 in.; the speed of this pulley is 300 revs. per minute. The diameter of the driven pulley C on the countershaft is 6 in.; the speed of the countershaft is therefore 600 revs. per minute. Ratio $\frac{B}{C} = \frac{12}{6}$, or 2 to 1.

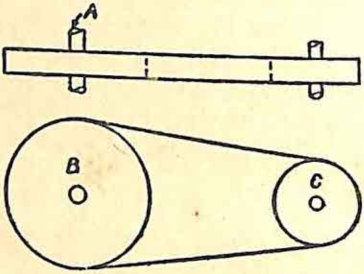


Fig. 191

Another example: B is 16 in. in diameter, and C 4 in. Ratio $\frac{B}{C} = \frac{16}{4}$, or 4 to 1. Hence if the main shaft speed is 300 revs. per minute, the countershaft speed is 1200 revs. per minute.

A further example may be given, in which the speed of the driven pulley is less than that of the driver. Main shaft speed, 300 revs. per minute. Diameter of driver B, 8 in. Diameter of driven C, 16 in. Ratio $\frac{B}{C} = \frac{8}{16}$, or 1 to 2; the speed of the countershaft is therefore 150 revs. per minute.

It will be seen that the pulley of smallest diameter is fixed on the shaft which is to have the greatest number of revolutions per minute.

It is also necessary to understand the principle of pulley speed calculations in order to fit pulleys which will give a required speed.

The principle is that the diameter of the driving pulley multiplied by its number of revolutions per minute is equal to the diameter of the driven pulley multiplied by its number of revolutions per minute.

Thus, for example, to find the revolutions per minute of a driven pulley, given its diameter, and also the diameter of the driving pulley and its revolutions per minute, multiply the diameter of the driving pulley by its revolutions per minute and divide by the diameter of the driven pulley. Similarly, to find the diameter of the driven pulley, given its revolutions per minute, and also the diameter and revolutions per minute of the driving pulley, multiply the diameter of the driving pulley by its revolutions per minute, and divide by the revolutions per minute of the driven pulley.

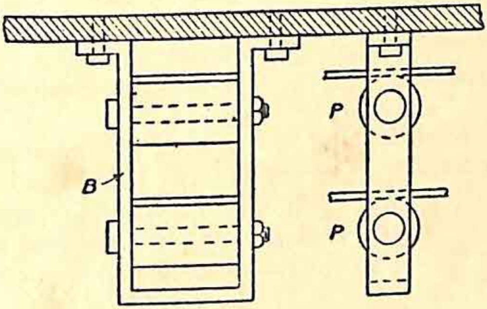


Fig. 192.—" Jockey " pulley

Long belts should be used in preference to short ones. It is often necessary to drive another main shaft, parallel to one already laid, with but one electric motor available. To do this, a pulley of a large diameter should be fixed to each shaft, and the pulleys connected by a wide belt. The distance between these two pulleys may be the width of the shop, and the weight of the belt over this distance would cause it to sag. It is then usual to fit what is known as a "jockey" pulley halfway between the two main-shaft pulleys, as shown in fig. 192. The two pulleys P, P (usually made from boxwood) are supported on spindles and revolve in the bracket B. The belt is thus prevented from sagging.

V-Belts

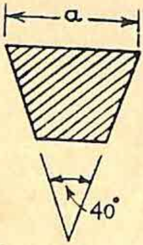
This type of belt has a much more powerful grip than the flat belt. It is very suitable for the drive from a motor to a machine or any other permanent drive.

The usual form of V-rope is made of rubber and canvas, and is made in one piece without a joint.

Standard sections of V-belting are as shown. Lengths can usually be supplied by the makers as required. (Fig. 193*a*.)

Because V-belts cannot be shortened it is important that efficient means should be provided for adjusting the centre distance of the pulleys. Fig. 193*b* shows some conventional methods. Where two belts are used in series it is most desirable that the action of tightening one belt does not loosen the other.

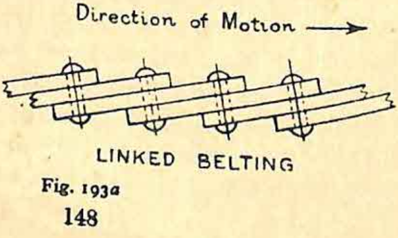
In some cases the impossibility of jointing a V-belt is a serious inconvenience and linked belting is used. This has equal gripping power with the endless V-belt but is very given to stretching. Such belts will only run well in one direction.



Section of Standard V belt

Standard dimensions

a	1½"	1¼"	⅞"	21/32"	½"	⅜"
b	1"	¾"	⅝"	7/16"	5/16"	7/32"



LINKED BELTING

Fig. 193*a*

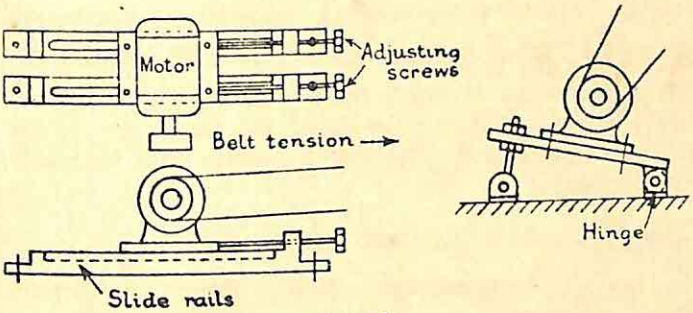


Fig. 193*b*

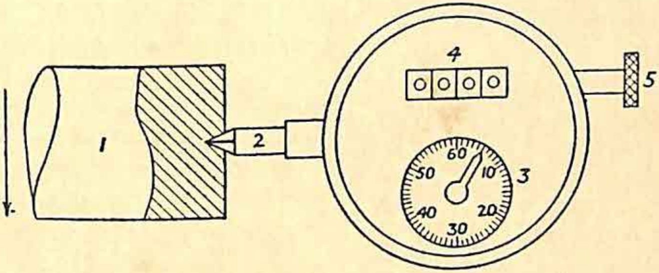


Fig. 194

Revolution Counter

In pulley and belt calculation it is necessary to have some means of counting the number of revolutions of the shafts. One type of indicator is shown in fig. 194. The instrument is held by the handle (5) and the spindle (2) is placed in the centre of the shaft (1). When the spindle (2) is pressed into the shaft (1), the clock (3), which registers seconds, is set in motion and at the same time the number of revolutions made by the spindle is shown on the indicator (4). If the spindle (2) is allowed to remain connected to the shaft while the hand of the clock (3) revolves once, this will equal 60 sec. or 1 min., and the number of revolutions the spindle has made during this time, will be recorded by the indicator (4); for example, | 3 | 2 | 4 | 6 |, 3246 revs.

per minute. After being used, the indicator should be set back to $\boxed{0}\boxed{0}\boxed{0}\boxed{0}$ by turning the handle (5). An instrument of this type is much more accurate than the one previously dealt with, as the speed and time mechanisms are synchronized, and neither will operate until the shaft (2) is revolved.

Belt Fasteners

The ends of belts are connected by means of different types of fasteners or lacing. Fig. 195 shows the Alligator steel belt lacing. Fig. 196 shows the Bristol pattern steel belt lacing. Fig. 197 shows Hicks belt hooks. These are all in common use and the type used depends on the width of belt.

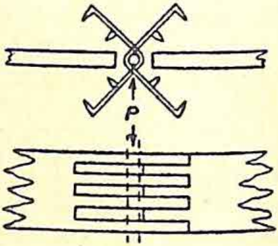


Fig. 195

Figs. 196 and 197 show permanent types, and it will be seen that these have to be cut to remove them from the machine.

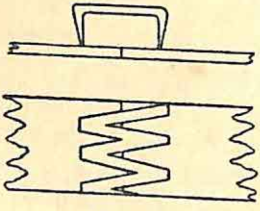


Fig. 196

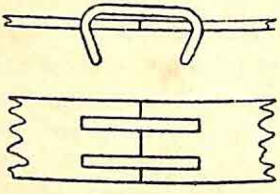


Fig. 197

The type shown in fig. 195 is not permanent; the belt can be removed from the machine by removing the pin P shown in the illustration.

CHAPTER XVIII

Methods of Securing Work to Machines

The securing of work to machines for the various operations such as milling, shaping, planing, drilling, boring, and lathe face-plate work, requires very careful consideration. Success lies in securing the work with a minimum of fixings, yet firmly and rigidly so that it will stand against the cutting thrust imposed by the tool, and also resist spring and distortion. The methods employed can be divided into five classes: (1) Machine vices; (2) clamping arrangements; (3) angle plates; (4) face plates; (5) fixtures.

The first four methods may be used when it is required to machine single pieces of work, but No. 5, the fixture, is a specially constructed appliance used for setting or holding a piece of work on a machine, in a definite position that may be needed for similar pieces.

Tee-slots

These specially shaped slots (fig. 198) will be found on machine tables to enable bolts to slide into any position for clamping the work.

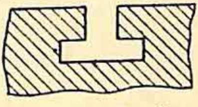


Fig. 198.—Tee-slot

Machine Vice

Many pieces of work are held in a machine vice (fig. 199, p. 153), the jaws of which are of ground hardened steel. All milling machine vices are made with great accuracy; they should be used for that machine only, not on a drilling machine, where they will be subject to rough usage which will destroy the excellent parallel finish of the jaws. The ordinary vice is made to swivel and has graduations marked round the base to show the angle at which it may be swivelled. These graduations are shown by B in the diagram; A represents the work being held, while P, P are parallel packing pieces placed underneath to prevent the work from getting out of parallel during the machining.

Clamps and Clamping

The use of any form of clamping arrangement requires skill and experience. Having in view the character of the work in hand, the operator should try to eliminate all dangers arising through spring or distortion. A comprehensive range of clips, bolts, plates, parallel strips, wedges, and packing blocks, &c., is usually available for use on any job that may be required. In addition to these, it will be found necessary from time to time to design clamps for special work. Small work when held on the table should be released slightly after the coarse cuts have been taken, so that when the finishing cut is being made, the work will take up its own position, relieved of bolting-down strain. This is very important, as it is easy to clamp work down so as to set up ulterior strains, with the result that when the work is taken off the machine table, its surface is found to have a twist or hollow.

Fig. 200 shows a simple form of clamping plate and bolt. The clamping bolt should be placed as near to the work as possible, so that the main pressure is on the work and not on the packing piece. This also helps to lessen table strain. The correct method is shown at A in the diagram; B shows the incorrect method. Another example of this method of clamping is shown in fig. 201.

A method of side clamping for thin work is shown in fig. 202, and this is a favoured method that is applicable when work of thin cross-section has to be machined. A pair of such clamps are used, one at each end. An exceedingly useful clamp is the thrust-block adjuster shown in

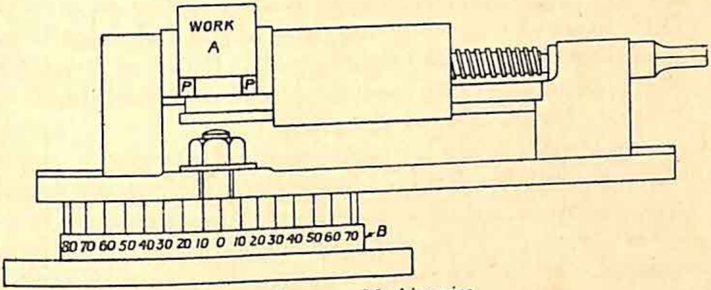


Fig. 199.—Machine vice

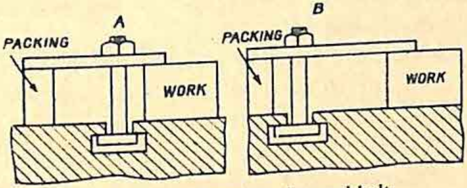


Fig. 200.—Clamping plate and bolt

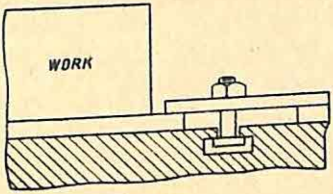


Fig. 201

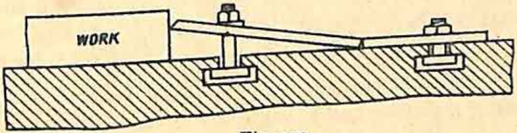


Fig. 202

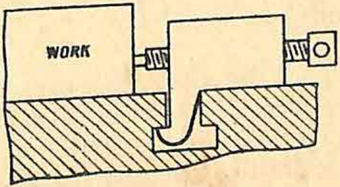


Fig. 203.—Thrust-block adjuster

fig. 203. This is made of mild steel or malleable iron, and is so shaped that it will drop into and remain firm in any of the tee slots on the machine table. It can be quickly set in position, is strong and rigid, and will withstand any ordinary thrust exerted against it.

Fig. 204 shows the U clamp, which is intended to replace the ordinary flat holding-down plate with a single hole. This clamp permits of a wide range of end movement and gives greater accommodation, because the bolt passes through the space between the parallel sides. It is much stronger than the flat plate, and is particularly adapted to the heavier classes of work.

Another form of clamping is used as shown in fig. 205, where a screw-jack is used as packing; this avoids the use of odd packing blocks, which are apt to be less rigid. Fig. 206 shows a small type which is very useful for small work; by means of the screw, it can be adjusted to accommodate varying thicknesses of work. Another form of adjustable clamp is shown in fig. 207. By the use of a hexagonal packing piece, to which the clamping plate is hinged, six different heights are obtainable.

Angle Plates

The use of the angle plate (fig. 208) is very much favoured when it is required to drill a hole, or machine a face, square with another face or edge. It is usually made to an angle of 90°, and forms a very convenient method of securing work of irregular shape. Any clamping method previously dealt with may be used, whichever is most convenient. A simple example is shown in fig. 209, where the work is set for either drilling or machining on a shaping or milling machine.

No standard can be set in this type of work, as conditions vary in almost every piece of work, and only after considerable experience is it possible to decide the best and quickest method of securing the work by the use of angle plates.

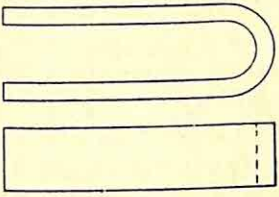


Fig. 204.—U clamp

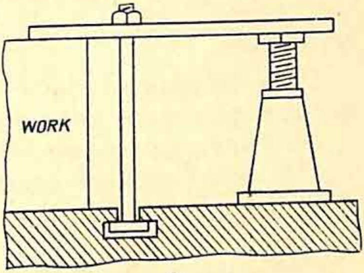


Fig. 205

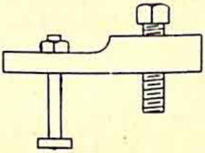


Fig. 206

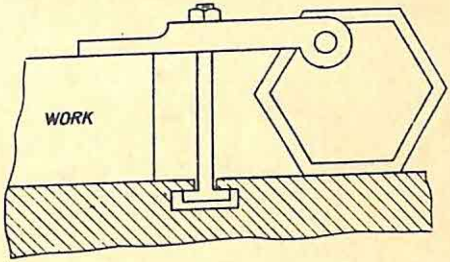


Fig. 207

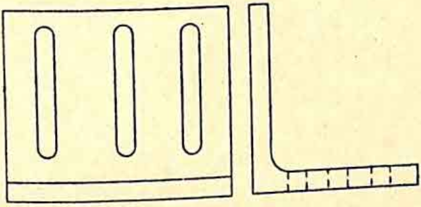


Fig. 208.—Angle plate

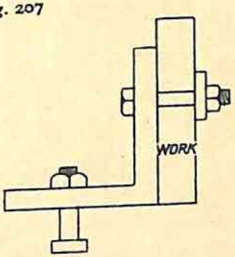


Fig. 209

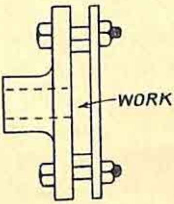


Fig. 210

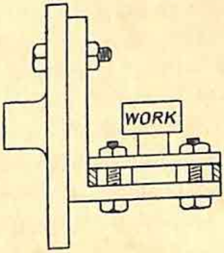


Fig. 211

Face Plates

The same applies to lathe face plates, where the setting of the work requires considerable skill.

The fixing can be direct to the face plate as shown in fig. 210, or the work may be fixed to an angle plate and then secured to the face plate by means of bolts as shown in fig. 211.

These examples of angle and face plate fixing methods naturally do not exhaust every possibility, but are merely intended to illustrate the principle involved, and the general lines to be followed. It may be useful to describe an example of a clamping arrangement specially designed for a particular piece of work.

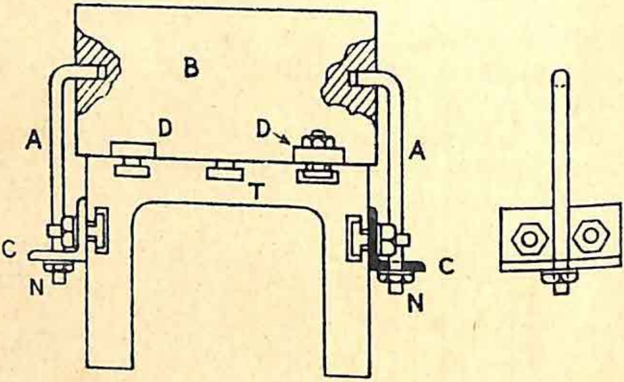


Fig. 212

The table of a shaping machine is narrow, and it is required to machine the face of a cast-iron block equal in width to the table.

The usual clamping methods cannot be used, as they may cover a small section of the face to be machined, and as the block is the same width as the table, the usual side clamping method cannot be used. Fig. 212 shows in elevation how the block B may be firmly held on the table T.

It is first necessary to drill a hole on each side of the block to accommodate the right-angled pieces of round rods A, A. These are held in position by angle brackets C, C and nuts, N, N. This will hold the block firmly to the table top, but two small blocks D, D must be bolted to the table as shown, to prevent any forward movement of the block during machining.

Vee Blocks

The drilling or machining of circular rods may be carried out by the use of vee blocks. Fig. 213 shows the rod held in position by a plate and packing piece bolted down securely. This method of fixing circular work can be adapted for various requirements.

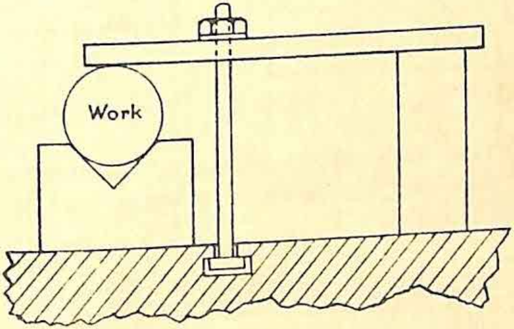


Fig. 213

Fixtures

When a number of similar pieces have to be machined, it is not economical to set up each piece separately, and some form of fixture has to be designed to meet the requirements of the work. As a complete survey of fixture designing would require a very lengthy explanation, we shall merely give two examples to illustrate the principle involved.

The fixture shown in fig. 214 will hold the work W securely to enable the face F to be machined, and the fixture is secured in position by the nut B. It will be seen that when the face F has been machined the

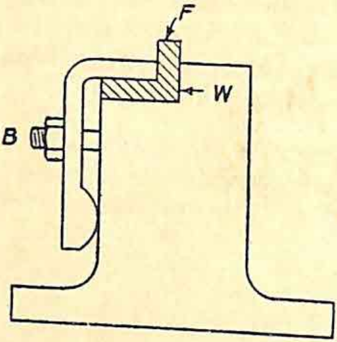


Fig. 214

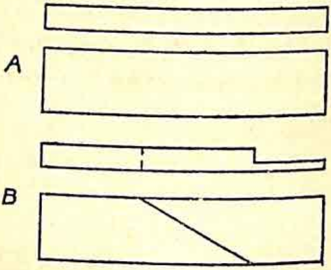


Fig. 215

work W may be quickly released by unscrewing the nut B, and then another piece of material can be quickly secured in position.

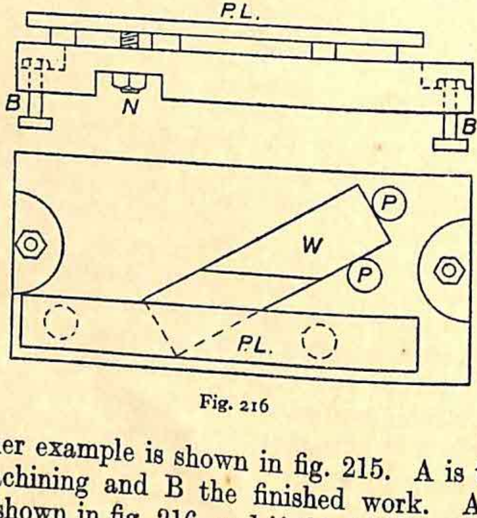


Fig. 216

The other example is shown in fig. 215. A is the metal before machining and B the finished work. A suitable fixture is shown in fig. 216, and if this is bolted parallel to the edge of the machine table by the bolts B, B, the fixture allows a cut to be taken across the work at an angle of 30°. The work W is held in position by the hardened steel pins P and securely held to the fixture by the plate P.L., which is held down by the bolt N. It will be seen that in this case also the work can be easily and quickly changed.

This fixture was designed as a special exercise in a school workshop to show the principle of machine fixtures, and proved very successful.

CHAPTER XIX

Casting, Forging and Welding

Castings are made by pouring molten metal into a suitable mould, and allowing it to solidify. Forgings are formed by squeezing, hammering, or stretching a lump of hot metal into the required shape. Both processes have their advantages and defects.

Casting

The oldest and most versatile method of casting is in sand moulds. Pages 163–4 show the method of making a simple hollow casting.

It will be noticed that with this casting there will be no special difficulty in separating the two halves of the mould (stage 3) if the pattern-maker has taken the precaution of tapering the nominally flat surfaces of the two flanges. The situation would be different if there were bosses on the backs of the flanges, and it would then be necessary to make the bosses as " loose pieces " so that they could be removed after the main body of the pattern. Much can be done in this way, but the design of difficult castings requires considerable experience, to know just what can and what cannot be done.

The defects in sand castings naturally arise from their method of manufacture. The commonest are as follows:

Blow holes. Bubbles of air or steam either on the surface or inside the metal.

Displaced Cores. This can make the thickness of cylinder walls uneven.

Displaced Boxes. Two halves of casting do not match.

Contraction Cracks or Stresses. As metal cools it shrinks. If the sections of the casting are very uneven some parts will cool before others and severe stresses will be set up, which may well lead to cracks. This is usually a fault of bad design.

Grain Growth. As the metal cools from the melting temperature, the grain tends to become coarse. This weakens the metal and is a fault of all castings.

Broken Mould.

Die Casting

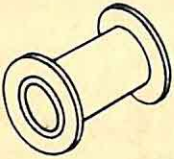
Sand casting is a slow process. Each mould must be prepared by hand and is destroyed when the finished casting is stripped. Some metals can be cast in permanent steel moulds or dies. This is a great economy where the number of castings to be made justifies the high cost of the dies themselves.

The metal may be poured either by hand or, when large numbers of small castings are wanted, in a casting machine. There is a tendency to reserve the term Die Casting for casting done in this machine, but here the term has been used in its general sense.

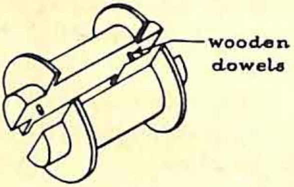
Metals for Casting

Naturally the easiest metals to cast are those with a low melting point. The following list gives the common metals along with their casting properties.

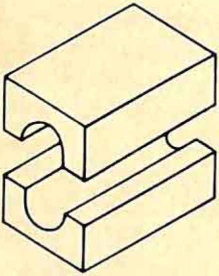
Metal	Melting Point, °C.	Usual Method of Casting	Remarks
Steel	1500	Sand	Difficult.
Cast Iron	1100	Sand	
Brass and Bronze	900	Sand or Die	Die casting difficult.
Aluminium Alloys	660	Sand or Die	Melting points given are those of the main constituents in pure form.
Zinc Alloys	419	Die	
Lead Alloys	327	Die	



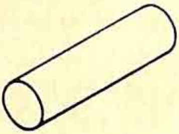
Casting to be made



Pattern

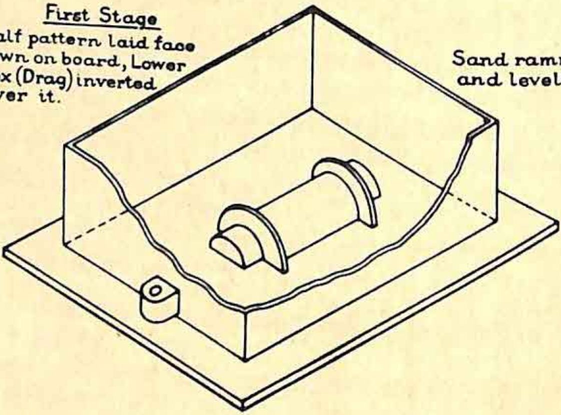


Core Box



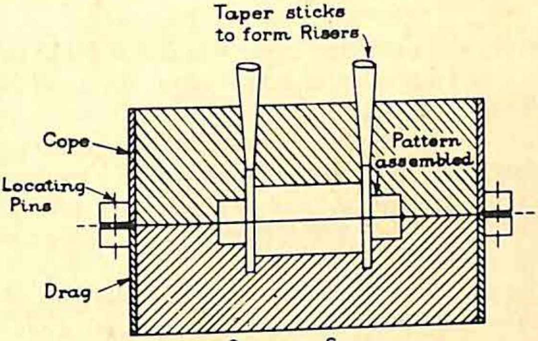
Core

First Stage
Half pattern laid face down on board, Lower Box (Drag) inverted over it.



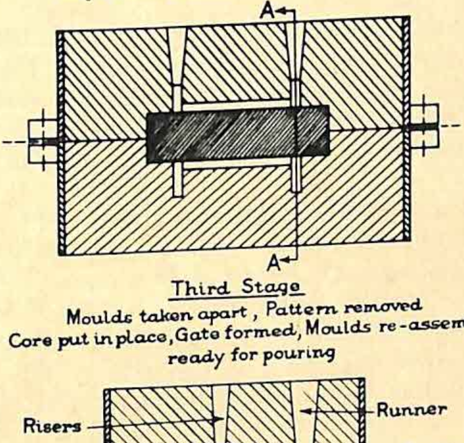
Sand rammed in and levelled off.

STAGES IN MAKING — —



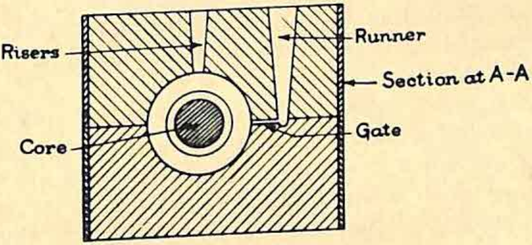
Second Stage

Parting face sprinkled with fine sand
Cope filled with sand and rammed



Third Stage

Moulds taken apart, Pattern removed
Core put in place, Gate formed, Moulds re-assembled
ready for pouring



— — A HOLLOW CASTING

Forging

The forging processes work on metal which is soft but not liquid. Force may be applied in many ways, the most important of which are shown below.

The Hammer is used for general work from horse shoes to crank shafts. In its power form it is worked by steam or compressed air. The face of the hammer head and anvil are normally flat but a large variety of special tools can be used for intricate work.

Hydraulic Press. This performs the same work as the hammer, but does it by a squeezing action instead of a blow. This action produces a rather tougher forging, but the equipment is larger and more expensive. It is used mainly for large and important forgings.

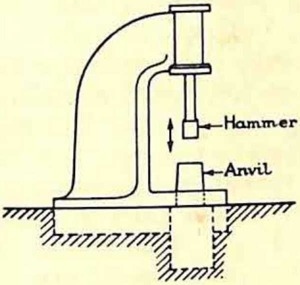
The Rolling Mill is used for making plates and bars. The rollers are geared together and power-driven. The gap is adjusted to the size required. The work passes through many pairs of rollers before reaching its final size. Parallel rollers are used for making plate, and grooved rollers for "sections".

Drawing is a process in which metal is pulled through a tapered hole which is smaller than its original diameter. Many passes are needed before the final diameter is reached. This process is used for making wire.

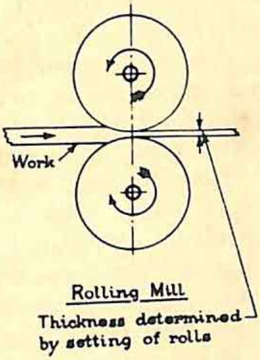
Extrusion is the reverse process to drawing. The metal is pushed through a tapered hole the size of the finished section. Only one pass is necessary or possible but great force is needed. It is widely used for "sections" of aluminium alloy.

These processes can be done either hot or cold depending on the metal, and the circumstances. Cold forging hardens all metals and if too much is done the metal will crack. In any case much of the ductility is lost. Hot forging does the metal no harm whatever; in fact it greatly improves its structure, and hence its toughness.

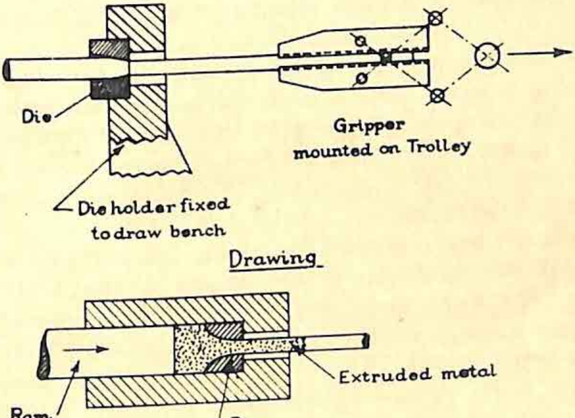
For ease of forging a metal needs a wide temperature range between the point at which it softens and the melting



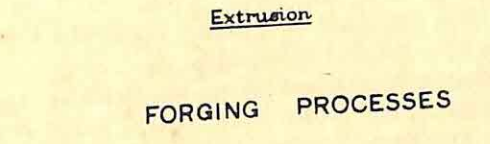
Hammer



Rolling Mill



Drawing



Extrusion

FORGING PROCESSES

point. Wrought iron is one of the most satisfactory metals in this respect, and mild steel is almost as good.

Welding, Brazing and Soldering

These are all methods of joining metals permanently by means of heat.

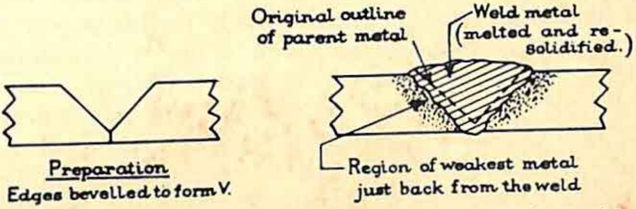
Fusion Welding is done by an oxyacetylene torch or by an electric arc. The mating surfaces are melted and extra metal (of almost the same composition) is fed into the " molten pool " by a welding rod, so that the gap is filled up. When the metal sets the joint should be one continuous piece of metal. This form of weld suffers from the high temperature at which it is carried out. Contraction on cooling and grain coarsening of the parent metal can be serious. Annealing can help but is not always practicable. Oxygen must be excluded from the hot metal either by a flux in the case of electric welding or by using a neutral flame.

Forge Welding is done by hammering the two surfaces together at a white heat. The metal is solid, but soft and sticky. Not all metals will weld in this way; it depends on the kind of oxide films that are formed on the metals, and their general forging properties. Wrought iron and steel are particularly suitable.

Brazing is a useful process for joining two surfaces where the metals are dissimilar or are otherwise unsuitable for welding. A brazing metal is used (usually a copper alloy) which has a lower melting point than either of the two surfaces being joined. The work is done with a flame in much the same way as oxyacetylene welding. A flux is always used to break down the oxide films on the surfaces so that the brazing metal will " wet " them.

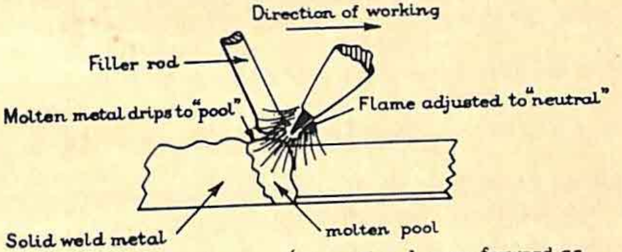
The actual joint is formed by an alloying of the brazing metal with the two metals being joined.

Soldering is done with lead-tin alloys, which all have quite low melting points. The solder is applied by a hot copper " bolt " (soldering " iron ") or by a gas flame, or by dipping the work in a molten bath. To get a good joint it is most


Original outline of parent metal
Weld metal (melted and re-solidified.)
Region of weakest metal just back from the weld

Preparation
Edges bevelled to form V.

Cross Section of finished weld

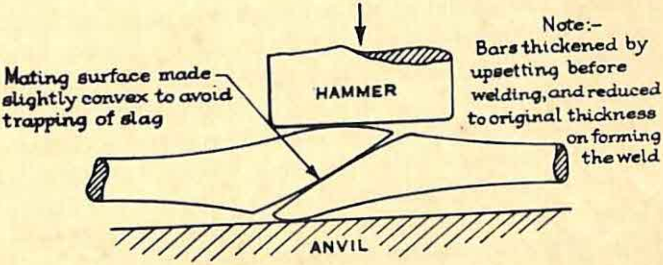


Note:- Several runs may be necessary when welding thick metal

(edges of pool creep forward as parent metal reaches melting point)

Longitudinal Section

OXY ACETYLENE WELDING


HAMMER
Mating surface made slightly convex to avoid trapping of slag
Note:- Bars thickened by upsetting before welding, and reduced to original thickness on forming the weld
ANVIL

FORGE WELD ON ROUND BAR

WELDING PROCESSES

important that the surfaces should be chemically clean. The use of the proper fluxes will help in this respect but general cleanliness is also necessary. Solder is weak in itself so that soldered joints should be made with good overlaps so as to spread the stress over a wide area. It is a good conductor of electricity so that it is widely used in electrical work. Plumber's solder is used for making wiped joints in lead pipe. It is of special composition, having a wide range of temperature at which it is in a pasty state. At this temperature it can be worked by alternate applications of a blow lamp and a wiping cloth, to build up the joint to the required thickness.

GREEK LETTERS

Several letters from the Greek alphabet are commonly used in the Technical Press; perhaps the most common are:
α (alpha), β (beta), γ (gamma), δ (delta), θ (theta), λ (lambda), μ (mu), π (pi), ρ (rho), Σ σ (sigma), φ (phi), ψ (psi), ω (omega).

GLOSSARY

Adjustable strips.—Metal strips used to compensate for wear of machine slides.

Adjustments.—Slight movements and corrections effected during the setting of work in machines.

Alignment.—Getting parts in line, such as lathe spindles and shafting.

Angle of tool.—The angle included between two faces of a cutting tool.

Angle plate.—A casting having machined faces at a definite angle to one another.

Annealing.—Softening hard steel to relieve it of internal tension, or to render it easy to machine.

Apron.—The part of a lathe saddle which hangs down in front.

Arbor.—A type of spindle or mandrel for holding cutters or work.

Automatic.—A movement or operation carried out by a moving mechanism without direct intervention of the operator.

Back-gear.—Toothed wheels used to gain power and transmit it back to the spindle.

Back-lash.—Jarring reactions on a piece of mechanism, caused by the wearing of threads or teeth.

Backing off.—Imparting clearance back from the cutting edges of tools and cutters.

Bed.—Any base or lower portion of a machine on which slides are set or moved.

Between centres.—Setting work for turning or grinding between the point centres of the fixed and loose headstocks.

Bevel gears.—Toothed gears, the pitch planes of which are conic frusta.

Boring.—The enlargement of a hole already existing, performed either by a lathe or on a special machine (see Drilling).

Box-tools.—Cutters held in cast-iron boxes, with steadies, to ensure uniform results in turning.

Brasses.—The loose lining of shaft bearings, made of brass, gun-metal, or white metal.

Broaching.—The process used to produce square or other special shaped holes.

Carrier or **Dog.**—A looped piece of steel which clips an object to be driven between centres.

Centre punch.—A pointed tool to be struck by a hammer to produce shallow depressions, such as a point for drilling.

Centring.—Marking the centre on shafts, bars, and other work.

Change wheels.—Toothed gears used to obtain speed ratios in screw-cutting, &c.

Chatter.—Vibration during machining, due to insufficient rigidity of the tool, work, or machine.

Chipping.—Cutting metal with a cold chisel and hammer.

Chuck.—Any appliance used for gripping work to be machined.

Chucking.—The attachment of work to lathe chucks and holders.

Clamping plates.—Plates used to hold work securely during machining.

Concentric chuck.—One in which the jaws are moved simultaneously (also termed **Self-centring chuck**).

Countershaft.—An intermediate shaft with belt pulleys, by which speed changes are obtained and machines are started and stopped.

Crowning.—Curved surface on the face of a pulley.

Dead centres.—Points which do not revolve.

Dead level.—Perfectly level.

Dead size.—Work produced to the exact dimensions required.

Die stock.—A screw-cutting appliance.

Draw-filing.—Smoothing a surface by working a file along it in a direction at right angles to the length of the file, and parallel with the work.

Drill.—The tool with which the boring of a hole is commenced.

Drilling.—The first operation in making a hole (using a drill) (see Boring).

Drunken screw or thread.—A screw thread which has a wavy outline.

External thread.—A screw cut on the outside of a cylinder.

Face-plate.—The disc screwed on to a lathe spindle nose, and slotted to receive holding-down bolts.

Facing.—Turning a plain surface.

Feed.—The amount of traverse of a tool or work during cutting.

Feed mechanism.—Devices employed to feed slides or spindles at a definite rate.

Female.—A recessed or internal portion of a fitting, e.g. a female gauge or female screw (see Male).

Fixture.—An appliance for setting and holding a piece of work on a machine in a definite fixed position. (Sometimes known as a **Jig.**)

Forming.—Turning irregularly-shaped pieces with tools of the same profile.

Friction clutch.—A clutch used in machine tool work for throwing movements in and out quickly.

Full thread.—A thread which is cut to its proper depth.

Gap lathe.—A lathe with a break in the bed to receive large objects.

Gauging.—Measuring work by methods of contact instead of with a rule.

Gear wheels.—Toothed wheels.

Grinding.—Term usually applied to work done on emery-wheel grinding machines with precision movements.

Hard metal.—Metal which is tooled with difficulty.

Headstock.—The driving head of a lathe or grinder.

Heavy cut.—A deep cut combined with a coarse feed.

High-speed tools.—Tools of self-hardening steel that cut rapidly, and are not injured by the high temperature developed in their use.

Idle wheel.—One which changes the direction of motion, or fills a space, without affecting velocity ratios.

In line.—Signifies a number of centres of facings in one horizontal plane.

Independent chuck.—A chuck whose jaws can be moved independently of one another.

Indicator.—An instrument which magnifies error in machine movements, and enables delicate tests to be made.

Internal thread.—A screw cut on the inside of a cylinder.

Lap.—A containing body of lead or cast iron charged with abrasive.

Lapping.—Grinding and polishing by means of a lap.

Lathe.—A machine which rotates work upon a plate or chuck or between centres, and cuts with turning tools.

Lead-screw.—The lathe screw, the pitch of which is the chief factor in screw-cutting.

Loose-centre.—The centre in a revolving spindle.

Machine tool.—A machine in which cutting tools are operated by power.

Machine vice.—A vice with a movable jaw, to hold pieces of work for machining.

Machining.—Cutting metal by the aid of machine tools of all types.

Main.—The principal element, e.g. main belt, main screw, main shafting, main pulley.

Male.—The external portion of a fitting, e.g. a male gauge or male screw.

Mandrel.—A spindle of a lathe head; also, a separate spindle on which work is held for machining.

Marking-off table.—A cast-iron table on which work is marked out.

Multiple cutting.—Machine operations employing several tools simultaneously.

Nose.—The front end of a spindle or mandrel.

Out of gear.—Toothed gears having their teeth disengaged.

Out of truth.—Inaccuracy in work.

Over all.—A dimension which is the sum of smaller dimensions in one plane.

Pitch.—The distance between centres of adjacent wheel teeth and threads, measured on the pitch line.

Planing machine.—A type of machine on which work usually travels on a table, under the tools.

Quick return.—The rapid backward movement of slides during the non-cutting stroke.

Rake.—The angle of cutting tools, e.g. front, top, or side rake.

Reamering.—Smoothing and finishing drilled holes with reamers.

Reboring.—Smoothing (with enlargement of) the bores of cylinders which have become inaccurate by wear.

Rechucking.—Putting work into a new position on a lathe chuck, to present a fresh portion for turning.

Roughing cut.—A first cut taken. It is coarse and heavy in comparison with a finishing cut.

Saddle.—A sliding portion of a machine, which carries other slides or rests.

Taking up.—The making of adjustments to compensate for the wear of slides and other fixtures.

Tapping.—Cutting internal threads with screw taps.

Tapping hole.—A hole drilled to the size of the bottom of a screw-thread to be cut in the hole.

Tee slots.—A special shape of slot, employed to enable bolts to be slid into any position for clamping work on tables.

Template.—A pattern from which a piece of work is lined out or machined.

Tommy.—A round bar used for insertion in a hole in circular nuts, to turn them.

Tool-holder.—A bar for holding and operating loose cutters.

Truth (To true).—Accuracy in machining and fitting.

Turnings.—The shavings and chips removed in lathe work.

Universal joint.—A pivoted joint employed to transmit motion to parts out of alignment.

Vee strips.—Angular strips by which adjustments are effected to compensate for wear.

Vertical.—Applies to the position of spindles, as in vertical drills and boring machines.

Work.—Commonly used in a concrete way, to denote any piece of material on which operations are being performed.

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